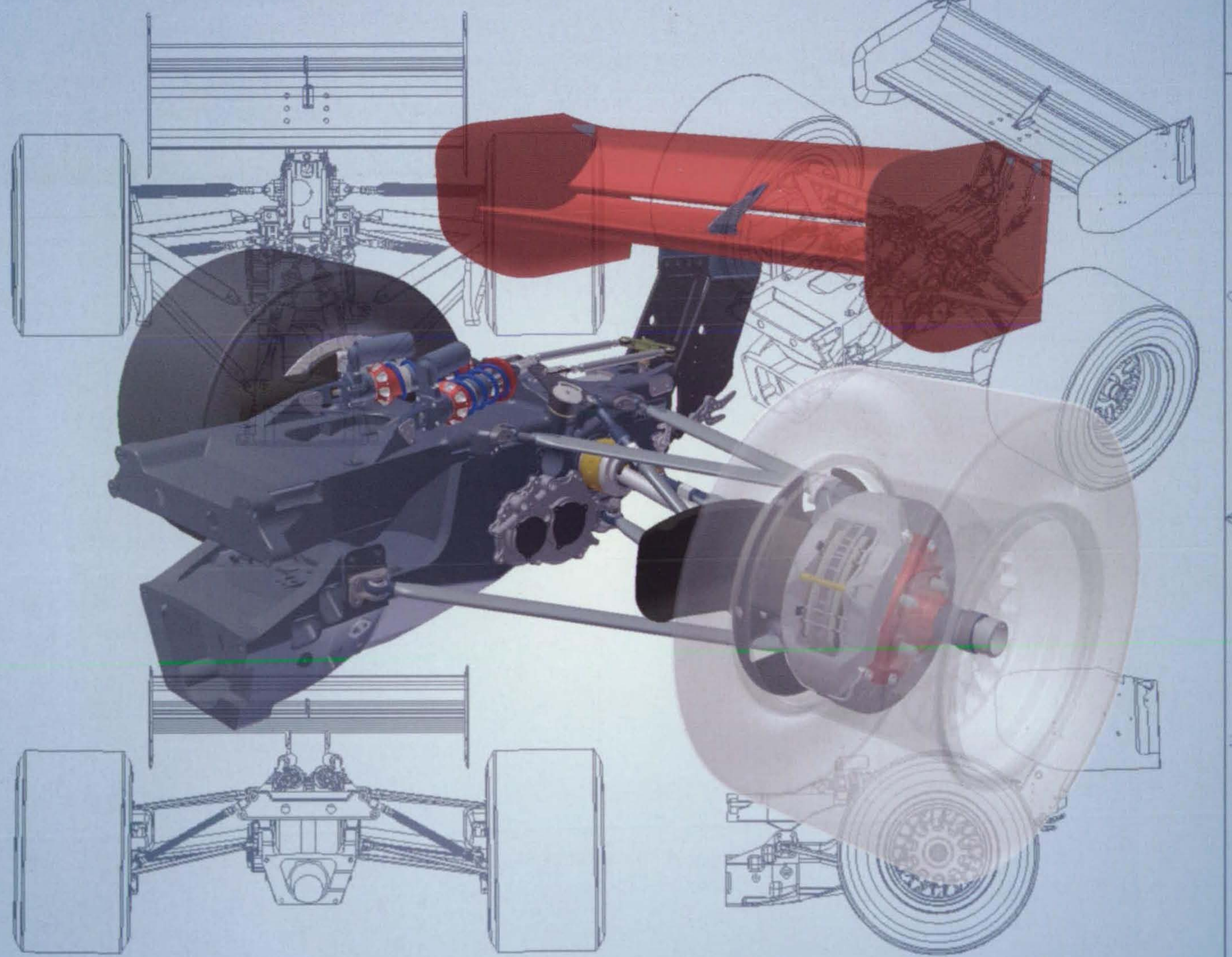
March 2002 www.nasatech.com Vol. 26 No. 3

TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING



A Changing Climate for CAD

Data Analysis Software Enables Real-Time Diagnosis of Complex Systems

Photonics Tech Briefs

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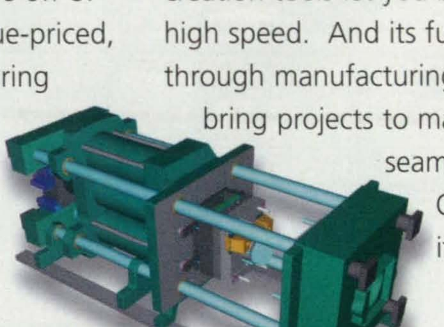

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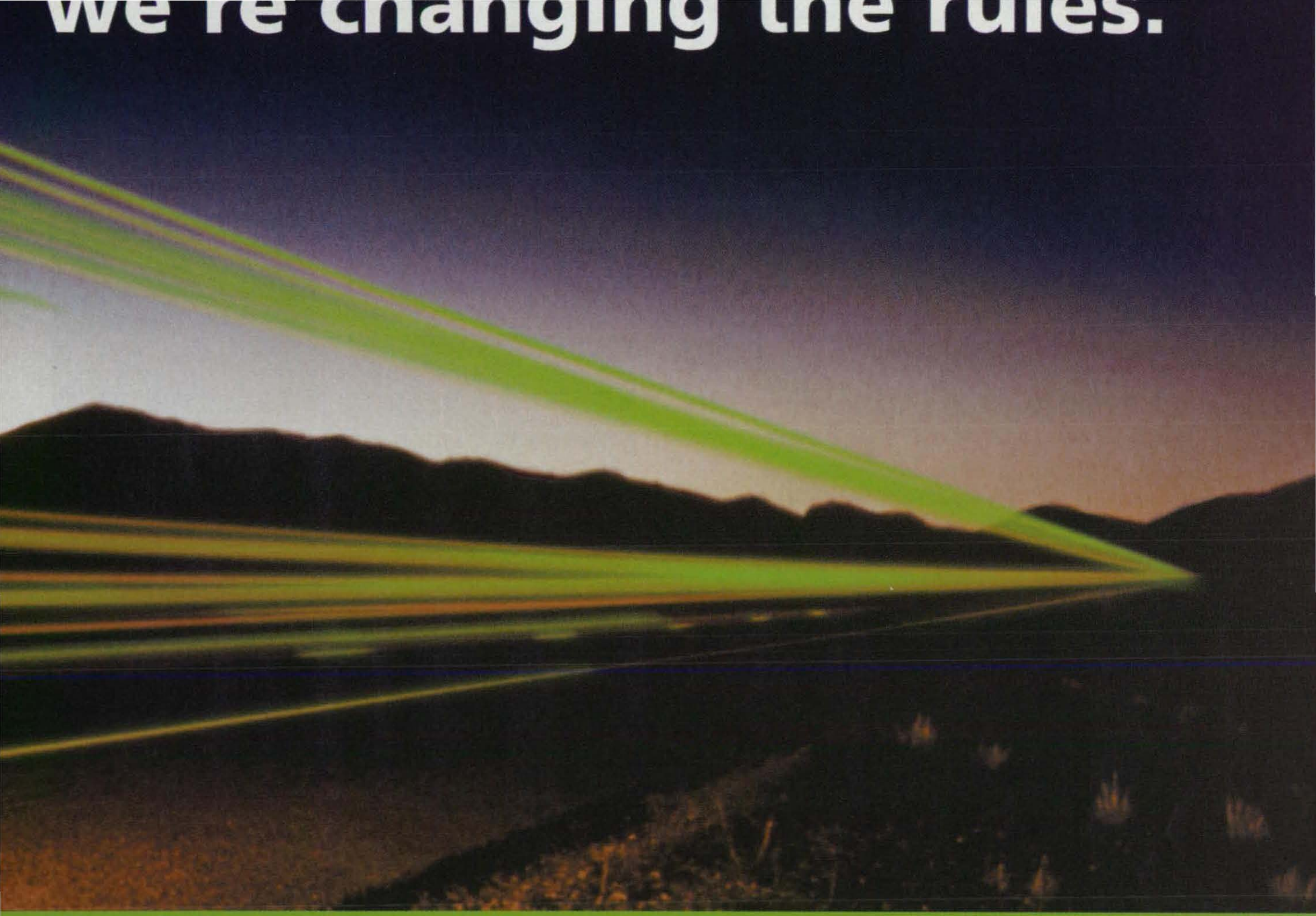

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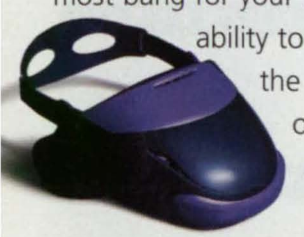

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TECH BRIEFS

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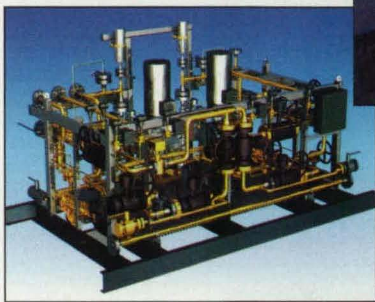

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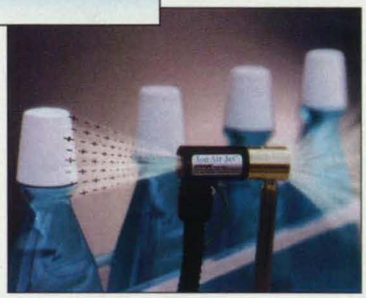

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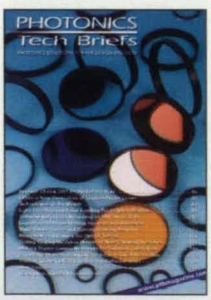
DEPARTMENTS

NEW FOR DESIGN ENGINEERS

SPECIAL SUPPLEMENT



Follows page 42 in selected editions only.

"The application of this software is universal - the only limit is in one's imagination."

-ALGOR customer **Phil Pisczak,** Preformed Line Products

National HDTV Conversion Effort Requires Re-Engineered Transmission Towers

Preformed Line Products (PLP®), a $200 million global leader in the manufacture of cable anchoring systems headquartered in Cleveland, Ohio, is contributing to the national conversion from analog TV to high-definition television (HDTV) with its ROCKET-SOCKET™ Dead-end for guy wires, which supports the transmission towers that will be taller, bigger and heavier to bear HDTV's dramatically improved wide screen digital audio/video information. PLP's customer base includes most of the nation's power utility providers and communication providers such as Verizon, Bell South and Adelphia in addition to a variety of resellers.

THE CHALLENGE

To design the dead-end to support the large communication/broadcast transmission towers that would withstand typical loads including 252,000 pounds of structural weight and wind loading as well as dynamic loads that might result from accidental impact.

THE SOLUTION

PLP engineers chose ALGOR to analyze the ROCKET-SOCKET design. PLP used the material austempered ductile iron for increased strength and toughness, rather than ductile iron, which they have used for other dead-end components. The geometry was modeled in PRO/ENGINEER, captured directly in ALGOR and then an impact analysis was performed with ALGOR Mechanical Event Simulation (MES) software. The result was a modification to the geometry of the ROCKET-SOCKET Dead-end to better withstand higher mechanical loadings. By using MES, PLP engineers were able to expedite the testing, reduce the number of iterations in the laboratory and get their product to market more quickly.

ALGOR®

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PRODUCT OF THE MONTH

The TPS600 rugged power supplies from Tracewell Power (Lewis Center, OH) provide a pluggable, multiple power supply backup for all equipment in a system.

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ON THE COVER

Created with Autodesk Inventor 3D design software from Autodesk (San Rafael, CA), this image details the right-side rear end of a race car by PacWest Racing Group of Indianapolis, IN. The 2D drawing and 3D solid modeling aspects highlighted in this image illustrate the migration of 2D to 3D that many CAD users are faced with today. The feature beginning on page 24 includes insights from CAD industry leaders on this and other issues facing the CAD market.

(Image created by John Helfen, Autodesk)

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TECH BRIEFS

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BPA INTERNATIONAL

Published by..**Associated Business Publications**
Publisher..**Joseph T. Pramberger**
Editor/Associate Publisher..**Linda L. Bell**
Editor, Market Focus Editions..**Robert Clark**
Associate Editor/Internet Editor..**Laura Raduta**
Production Manager..**Joanne Gaccione**
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Senior Designer..**Christopher Coleman**
Circulation Manager..**Hugh J. Dowling**

BRIEFS & SUPPORTING LITERATURE: Written and produced for NASA by **Advanced Testing Technologies, Inc.,** Hauppauge, NY 11788

Technical/Managing Editor..**Ted Selinsky**
Sr. Technical Analyst..**Dr. Larry Grunberger**
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NASA Tech Briefs are provided by the National Aeronautics and Space Administration, Technology Transfer Division, Washington, DC:

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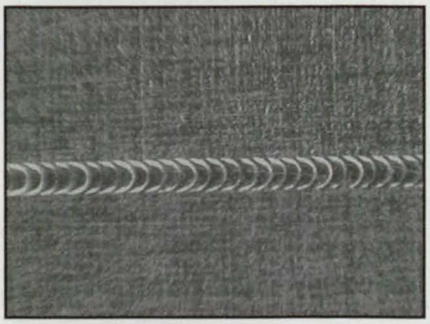
CO_2 Laser Applications of the Month

SYNRAD®
An Excel Technology Company

Welding Copper-Nickel Foil with CO_2 Lasers



A weld created using a Synrad CO_2 laser on copper-nickel foil.

CO_2 lasers are useful in a broad range of welding applications. The photo to the left shows the results of welding 0.0025"-thick sheets of copper-nickel alloy foil. Used in aerospace, automotive, and many other industries, the material was welded with a Synrad Evolution™ 125-watt laser. The weld was made at a velocity of 110" per minute with a 2.5" focal length lens having a spot size of 0.004". Argon gas, at 2 psi, was used for shielding.

The key to achieving virtually no heat deformation and a uniform weld bead is in selecting proper pulsing parameters for the laser. In this case, a pulse frequency of 685 Hz and a pulse length of 880 microseconds provided the weld characteristics desired. Changing the thickness or width of the weld bead is simply a matter of experimenting with variations in beam velocity, pulse frequency, or pulse length.

Laser Cutting Urethane Bushings

The 2.5"-thick urethane bushing shown to the right was cut in nine seconds while being rotated underneath a 240 watt CO_2 laser beam. Although a slight discoloration is present, no charring of the urethane material occurs.

To cut the material, a 7.5" focal length lens with a 0.5" depth of focus and a 0.012" spot size was used. The bushing was rotated at 140 rpm during cutting, which took nine seconds (21 revolutions). Nitrogen assist gas at 20 psi was used while cutting.

This Urethane Bushing was cut with a 240 watt Synrad laser.

Laser Marking Fast Bar Codes on Inked Paper

This 24 character Code 128 bar code, including human-readable text, was marked on inked paper in only one second! The bar code, measuring 1.5" long by 0.5" high, was marked by a marking head and Synrad laser driven by WinMark Pro™ laser marking software. 20 watts of laser power were used to achieve a velocity of 250" per second.

Using a Synrad 25 watt marking system, these codes were marked at 250" per second!

Discover more CO_2 laser applications! Sign up for our monthly online Applications Newsletter at ***www.synrad.com/signup1***

*All applications on this page were processed at **Synrad's Applications Laboratory**. Synrad, the world's leading manufacturer of sealed CO_2 lasers, offers free process evaluations to companies with qualified applications. Call 1-800-SYNRAD1 for more information.*

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NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. Call (609) 667-7737 for the FLC coordinator in your area.

NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

Ames Research Center
Selected technological strengths: Information Technology; Biotechnology; Nanotechnology; Aerospace Operations Systems; Rotorcraft; Thermal Protection Systems.
Carolina Blake
(650) 604-1754
cblake@mail.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Jenny Baer-Riedhart
(661) 276-3689
jenny.baer-riedhart@dfrc.nasa.gov

Goddard Space Flight Center
Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Remote Sensing; Command.
George Alcorn
(301) 286-5810
galcorn@gsfc.nasa.gov

Jet Propulsion Laboratory
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Merle McKenzie
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Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Charlene E. Gilbert
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Kennedy Space Center
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Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Sam Morello
(757) 864-6005
s.a.morello@larc.nasa.gov

John H. Glenn Research Center at Lewis Field
Selected technological strengths: Aeropropulsion; Communications; Energy Technology; High Temperature Materials Research.
Larry Viterna
(216) 433-3484
cto@grc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Vernotto McMillan
(256) 544-2615
vernotto.mcmillan@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Kirk Sharp
(228) 688-1929
kirk.sharp@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

Joseph Allen
National Technology Transfer Center
(800) 678-6882

Ken Dozier
Far-West Technology Transfer Center
University of Southern California
(213) 743-2353

James P. Dunn
Center for Technology Commercialization
Westborough, MA
(508) 870-0042

B. David Bridges
Southeast Technology Transfer Center
Georgia Institute of Technology
(404) 894-6786

Gary Sera
Mid-Continent Technology Transfer Center
Texas A&M University
(409) 845-8762

Charles Blankenship
Technology Commercialization Center
Newport News, VA
(757) 269-0025

Pierrette Woodford
Great Lakes Industrial Technology Transfer Center
Battelle Memorial Institute
(216) 898-6400

NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

Carl Ray
Small Business Innovation Research Program (SBIR) & Small Business Technology Transfer Program (STTR)
(202) 358-4652
cray@mail.hq.nasa.gov

Dr. Robert Norwood
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(202) 358-0706
gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

Wayne P. Zeman
Lewis Incubator for Technology
Cleveland, OH
(216) 586-3888

B. Greg Hinkebein
Mississippi Enterprise for Technology
Stennis Space Center, MS
(800) 746-4699

Julie Holland
NASA Commercialization Center
Pomona, CA
(909) 869-4477

Bridgette Smalley
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Houston, TX
(713) 743-9155

John Fini
Goddard Space Flight Center Incubator
Baltimore, MD
(410) 327-9150 x1034

Thomas G. Rainey
NASA KSC Business Incubation Center
Titusville, FL
(407) 383-5200

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(256) 704-6000

Joe Becker
Ames Technology Commercialization Center
San Jose, CA
(408) 557-6700

Marty Kaszubowski
Hampton Roads Technology Incubator (Langley Research Center)
Hampton, VA
(757) 865-2140

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.

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SSMDR

V-83

ME-1000

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UpFront

PRODUCT OF THE MONTH

The TPS600 rugged power supplies from Tracewell Power, Lewis Center, OH, are designed for applications requiring uninterrupted operation, including computer, data storage, and telecon/data communications. The five-output TPS600 supplies up to 600W at 50°C, and up to 420W at 70°C. Multiple output configurations are available to cover a range of power requirements. The units are compatible with N+1 redundancy configuration, providing a pluggable, multiple power supply backup for all equipment in a system. All input and output connections are through a single, rear-panel, 60-pin connector that provides hot-swap capability for standard card or power backplanes. LED status indicators on the front panel show input and output OK. Interface signals meeting CompactPCI Power Interface specs are available for controlling and monitoring the power supply.

For Free Info Circle No. 715 or Enter No. 715 at www.nasatech.com/rs

NASA Welding Technology Hits the Market

Two commercial companies — MTS Systems of Eden Prairie, MN, and MCE Technologies of Seattle, WA — have successfully commercialized a welding tool developed at NASA's Marshall Space Flight Center in Alabama.

Friction stir welding uses the high rotational speed of a tool and the resulting frictional heat created from contact to "stir" together and bond two metal alloys. The process, however, relies on a single-piece pin tool, which can leave "keyholes" when welding cylindrical objects. The Marshall team designed an automatic retractable pin tool that uses a computer-controlled motor to automatically retract the pin into the shoulder of the tool at the end of the weld, preventing keyholes.

MTS Systems used the pin tool technology in its recent friction stir welding process system. Used by automotive, shipbuilding, and other industries, the system has proven cost-effective and efficient.

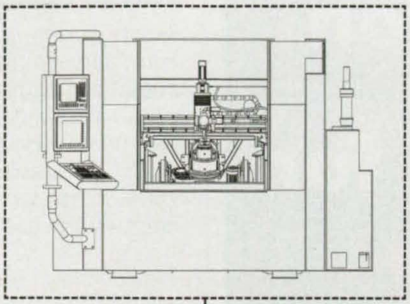
MCE Technologies (MCETEC) developed a line of production stir welding equipment using Marshall's pin tool for welding high-performance aluminum alloys. MCETEC's use of the NASA technology has contributed to production advantages such as reduced contamination and greater joint strength.

For more information on this and other NASA Marshall technologies available for commercialization, visit ***www.nasasolutions.com*** .

MCETEC's friction stir welding equipment incorporates NASA Marshall's pin tool technology.

Next Month in NTB

In the April issue, the winners of the 2001 Readers' Choice Product of the Year Awards will be featured. We'll let you know which product you chose as the most significant new introduction to the engineering community last year. Also, look for our preview of the Sensors Expo, which will highlight the hottest sensor products that will be on display at the show in San Jose in May.



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Reader Forum

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I am exciting a small PZT in shear mode, over the range of 1.7 to 3.3 MHz, with a variable-amplitude source. To close an amplitude control loop, I'd like to measure the motion envelope, which is on the order of 0 to 10 microns, with a very small sensor (large laser interferometry is not possible). In addition, I have multiple assemblies spaced horizontally over an area of roughly 1/4" by 4". The units and the individual sensors must be housed in an enclosure with vertical cross-section dimensions of about 18 mm by 4.5". Each PZT is vibrating a cone-shaped element, about 0.2" in diameter at its base, and 0.5" tall. I must sense motion at the tip of the cone. What about detecting a projected image on a semiconductor sensor? Any sensor sources that I can investigate? Thanks.

Rudy Schneider
rudy.schneider@noveraoptics.com

We are currently working on developing a wireless video system to be used in a sports-related environment that demands constant movements by the wearer of our micro-video cameras. We have tested 2.4 systems and have seen very poor results. All of our tests have been with portable transmitters and receivers. We are about to try patch antennas worn on both sides of the athlete's body going to a portable 2.4 receiver. It's been suggested that we try a YAGI antenna for receiving, and hopefully by combining a dual patch antenna system, this will work. If anyone has any other suggestions or can direct us to a reliable source of miniature equipment for transmitting and receiving, it would be greatly appreciated. Also, if anyone has information on a repeater design to send the signals to other portable stations, that would be welcomed. Size and weight are concerns in all cases.

Michael Jones
concepts@capital.net

I am a chartered physiotherapist interested in looking at hyperbaric medicine for the treatment of soft tissue injuries, including grade two ankle sprains. Has any research been done using the lightweight chambers for such use, and how can I find details on where to obtain one? Thank you.

Jo Shepherd
physio.jo@virgin.net

Who's Who at NASA

Dr. Jim Weiss, Chief Engineer and Technologist, Earth and Space Sciences Division, Jet Propulsion Laboratory

Dr. Jim Weiss is the Program Manager for Collaborative Neural Repair at NASA's Jet Propulsion Laboratory in Pasadena, CA. His team is working to develop a robotic device that will aid patients with spinal cord injuries.

***NASA Tech Briefs:* What is the device, and how will it work?**

Dr. Jim Weiss: The original idea was to develop something that could be used for the rehabilitation of people with spinal cord injuries and also the training of astronauts. The device has not been built yet. We're currently doing the design work and testing some of the components. A patient will be suspended on a treadmill by lines connected to an overhead hoist. The robotics will be attached to the patient's legs and to the treadmill in the form of a motor. The motor is going to monitor and control the movement of the person while they're walking on the moving treadmill. Basically, we'll put someone on the treadmill, start the treadmill, and then use robotic arms attached to their knees to help them walk.

The device will help prepare astronauts for work in space. One of the problems of being in a zero-gravity environment is that you don't utilize your legs, and your neurology forgets how to function properly. So when you return to Earth and you've not used your legs, you've forgotten how to use them. They're weak and they're atrophied.

There is a central pattern generator in one's spinal cord that controls the motion of locomotion — all the fine motor functions that control the muscles — and if that's not refreshed on a regular basis, it forgets and starts learning a new environment as part of being adaptive. We would use this to train astronauts for different environments, so when they return to Earth, they would be able to walk normally.

NTB: Do you see any other applications for this device?

Dr. Weiss: There are other things that it could be used for, such as training football players to sprint faster, or to help basketball players perform with more power. So, you could actually train the human body to operate better at sports like volleyball, basketball, football, or baseball.

Also, it would be applicable for controlled exercising. You could have controlled exercise, for instance, if a patient has a knee, ankle, or hip injury, or they've had some serious surgery on their leg and they've got to exercise to regain strength. When you've got an injury, you favor the other limb. This system could be used to make sure a patient doesn't favor the other limb so they re-learn normal function, and movement is complete. I've only spoken of the applications that are leg-dominant. You could do the same things with arms and other parts of the body. Motion is what we're really focusing on.

NTB: Who are NASA's partners in the research and development?

Dr. Weiss: UCLA was our primary partner in this. There's more in the development; it's now expanded to a collaboration with the University of California Irvine. There also has been a company formed around this technology called Robomedica, and they're raising funds to start the development of this technology.

NTB: When will it be available for clinical trials or actual use?

Dr. Weiss: I hope it will be available in three years; it depends on our ability to raise funds. Robomedica had their first round of funding and they've raised enough to get started. So, I think it's going to be 18 months to two years to get a product ready for testing.

*A full transcript of this interview appears on-line at **www.nasatech.com/whoswho**. Dr. Weiss can be reached at james.r.weiss@jpl.nasa.gov.*

NASA Patents

Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. The agency has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

Compact Dexterous Robotic Hand

(U.S. Patent No. 6,244,644)

Christopher Scott Lovchik and Myron A. Diftler, Johnson Space Center.

The present invention is intended to give a robotic hand the anatomical movement of the human hand yet to make it lightweight, mobile, and capable of grasping both heavy and light objects with precision. The robotic hand includes highly reliable yet simple components that enable the desired movements of a plurality of flexible fingers attached to a palm housing, a thumb, and a wrist member. Force is mechanically transmitted from drive components in a forearm portion through the wrist section to operate fingers and thumb. The dexterous robotic hand described herein generally consists of, in addition to a palm housing, fingers, and a thumb, a forearm section that houses the drive motors and electronics that enable the controlled movement of the fingers and the thumb. The device includes a two-degree-of-freedom wrist section and a twelve-degree-of-freedom hand.

Piezoelectric Vibrational and Acoustic Alert for a Personal Communications Device

(U.S. Patent No. 6,259,188)

Inventors: Stanley E. Woodard, Richard F. Heilbaum, Robert H. Daugherty, Raymond C. Scholz, Bruce D. Little, Robert L. Fox, Gerald A. Denhart, SeGon Jang, and Rizza Balcein, Langley Research Center.

A team at Langley Research Center identified a need for a combination vibrating and acoustical alarm mechanism that has a relatively uncomplicated design, is relatively inexpensive to produce, that is substantially durable, and is lightweight and small enough to be incorporated into a handheld communication device (PCD). It should provide an alert apparatus that includes a mechanically prestressed piezoelectric wafer inside the PCD and an alternating voltage input line coupled at two points on the wafer where polarity is recognized. The apparatus would also have a variable frequency device coupled to the voltage input line so that the alternating voltage on the input line would have a first frequency and a second frequency. The first would preferably be high enough to cause the wafer to vibrate at a resulting frequency that produces a sound perceptible by the human ear, and the second would preferably be sufficiently low to cause the wafer to vibrate at a frequency that would produce a vibration readily felt by the holder of the PCD.

Stable Algorithm for Estimating Airdata from Flush Surface Pressure Measurements

(U.S. Patent No. 6,253,166)

Inventors: Stephen A. Whitmore, Brent R. Cobleigh, and Edward A. Haering Jr., Dryden Flight Research Center.

Airdata are those parameters, characteristics, properties, and quantities derived from the air surrounding a flight vehicle. Accurate airdata are absolutely necessary for many purposes and applications, and help to ensure efficient and safe flights. But systems developed to date have proven highly inaccurate. There are several problems with existing algorithms. One is that the nonlinear regression method used in the estimation algorithm tends to be highly unstable. This unstable algorithm leads to the problem of complexity. The present invention is embodied in an airdata estimation and evaluation system and method for estimating and evaluating airdata from nonintrusive surface pressure measurements. It includes a triples formulation module for eliminating the pressure-related states from the flow model equation, an angle of attack module for computing that angle, an angle of sideslip module for computing that angle, and an airdata module for estimating and evaluating other airdata.

For more information on the inventions described here, contact the appropriate NASA Field Center's Commercial Technology Office. See page 12 for a list of office contacts.

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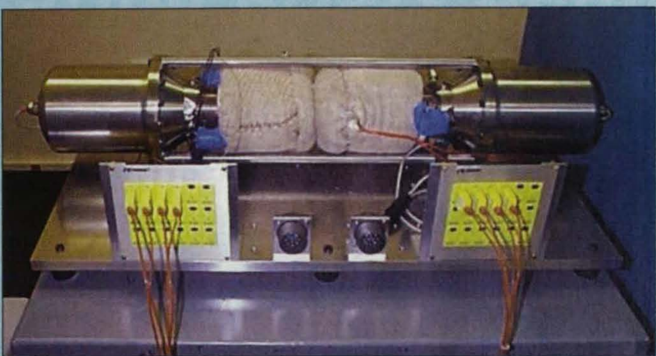
A free-piston Stirling converter is being developed by the Department of Energy, NASA's Glenn Research Center in Cleveland, OH, and Stirling Technology of Kennewick, WA.



Dual-opposed Stirling converter during test at NASA Glenn.

The converter will be utilized on the Stirling Radioisotope Generator (SRG), which is being constructed to provide electric power for unmanned Mars rovers and potential NASA deep space missions of long duration. To evaluate various 3D geometries, materials, and excitation levels on the converter, NASA engineer Steven M. Geng used Maxwell 3D Field Simulator to perform electromagnetic modeling.

"Glenn researchers are conducting a variety of in-house tasks to provide data in developing the Stirling converter for readiness for space qualification and mission implementation. Our work helps determine if a design will perform and function properly with the capability of surviving in a deep space or Mars surface environment," said Geng.

The converter is also being designed to survive a high-radiation environment such as a potential mission to Europa, one of Jupiter's moons. So far, the converter has passed launch environment random vibration testing at workmanship, flight acceptance, and qualification test levels while operating at full stroke and full power.

Geng said that the Maxwell software helped him and his colleagues investigate new methodologies to both improve designs and analyze existing designs. NASA is evaluating the magnets used in the converter's linear alternator. "Using Maxwell, we studied the magnets and the alternator to estimate the magnet's margin to demagnetization," said Geng.

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3D Measuring System Helps Build Rocket Bodies

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The two solid-rocket bodies of the Space Shuttle are able to resist loads of launch because they are forged from D-6 tool steel, and are nearly indestructible. Ladish forges all of the cylinders and domes that form the solid rocket motor cases. To assess the exact shape of each forging prior to machining, technicians previously measured each newly forged dome with a portage CMM to guide them in setting up the piece to be machined. This technique usually took two weeks to finish, and the 2D image generated was not always complete.

To generate a more detailed digital image of the rough-forged dome, Ladish engineers began using a FaroArm, a portable, 3D measuring system from Faro Technologies. The arm is an articulating instrument that employs optical encoders at the joints to provide X-Y-Z position and I-J-K orientation data to a computer. Dimensional tolerances are as close as ± 0.001", and it can measure any point within its spherical reach.

Ladish uses the arm for conventional dimensional checking by gathering a "digital cloud" of data consisting of up to 200,000 streaming points on each piece. After the data is collected in the arm's companion software, an accurate 3D reproduction of the dome is created. According to Ed Pastorek, Ladish's supervisor of product assurance, quality, and technology, the technique provides near-perfect parts. "This has given us a 'no-mistake' way to align and machine these parts," said Pastorek. "Now we know exactly what metal we have to take off."

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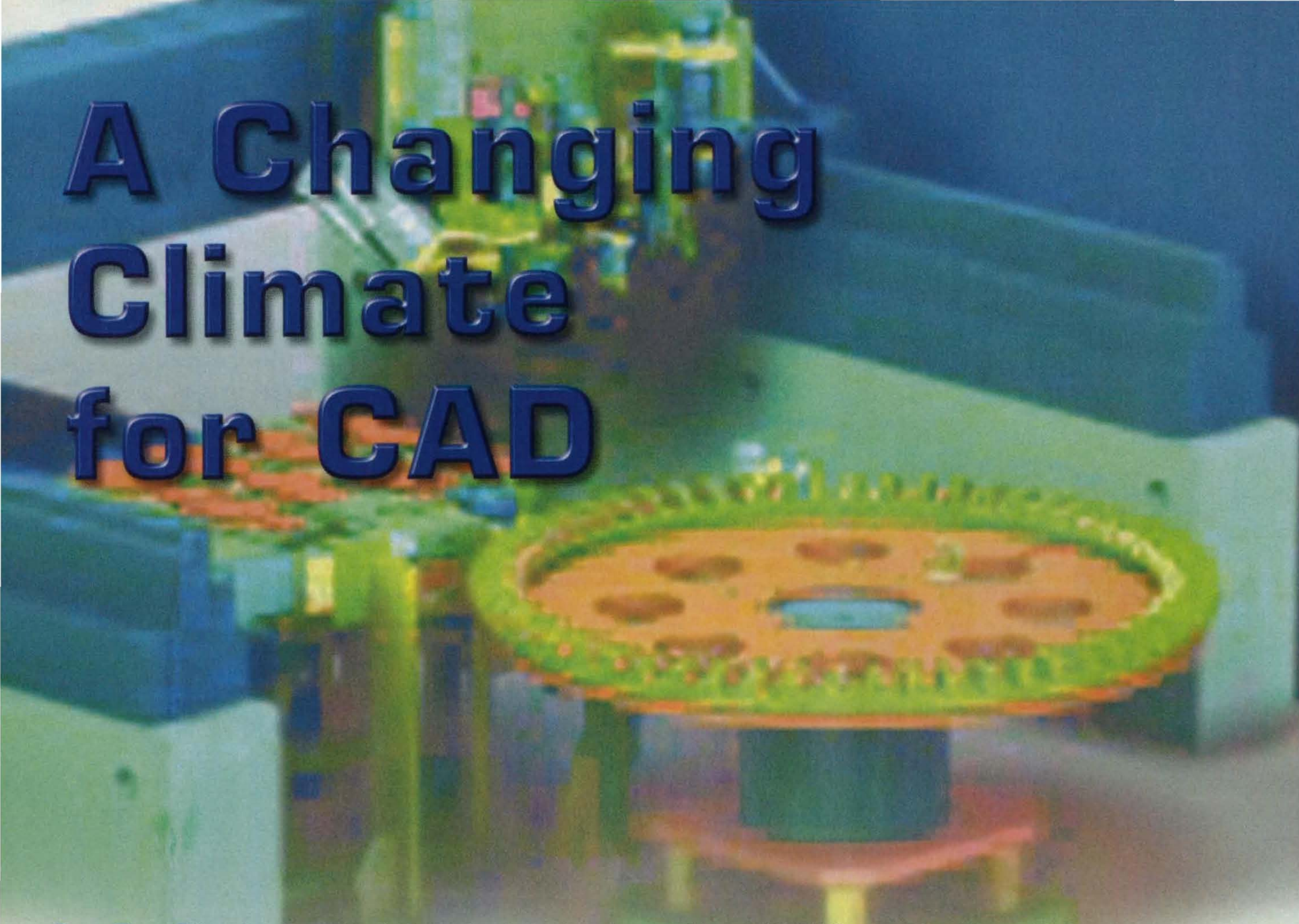
A Changing Climate for CAD



When we last visited the state of the CAD industry in March of 2001, the industry leaders we interviewed focused on the Internet, ease of use, and consolidation of CAD vendors. For this year's look at CAD, our experts were outspoken on ease of use, 2D to 3D migration, and how the changing economic climate has affected the CAD software market.

As a general rule, most of the vendors we interviewed are not changing their marketing strategy for new customers as a result of the economic downturn. If anything, many vendors are focusing more on their current customers than targeting new ones.

"We're marketing to the people who are already our customers," said John McEleney, CEO of SolidWorks. "As the economy gets a little more challenging, and some of our competitors try to drive their price down in the market, the one good thing about having a large installed base is that you're going back to people you already have a relationship with, so your cost of sales should be lower," he explained.

"Our initial installed base provides a very rich, fertile ground for continued building of those relationships and a nice business. There is a lot of opportunity for new business," said Brian Shepherd, senior vice president of MCAD technical marketing for PTC. "A lot of companies feel they need to be ready when the economy turns with a stable full of great products. The way they cut costs in the short term to weather the storm usually starts in their manufacturing organization where they ramp down production. They're trying to minimize physical inventory, but they're still very focused on creating intellectual inventory," Shepherd added.

Some vendors such as VX Corporation, a CAD/CAM supplier, are actually increasing their marketing efforts. "It's a real opportunity at this point," said Bob Fischer, vice president of sales and marketing for VX. "Companies have to do as much as before but with fewer people. We've changed the amount of face time, doing things like Web seminars. We need to go to the people — they won't come to us."

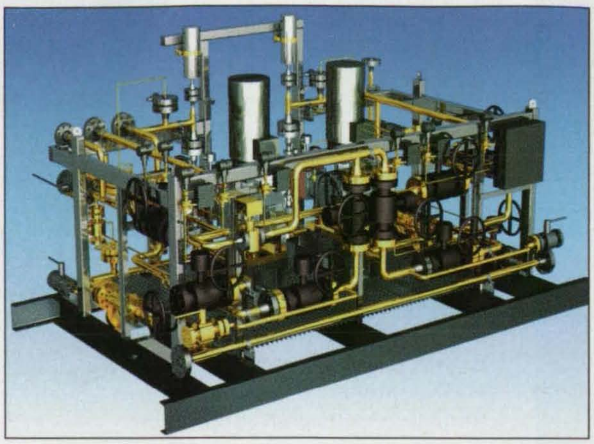
While much attention has centered around the economy since September 11, there were signs of a downturn at least six months before that, according to David Primrose, MCAD product marketing director for EDS PLM Solutions. "The economy took a knock, but life goes on, and people are purchasing products that have to be manufactured. In economic times like these, companies turn to tools that will increase their productivity and help recover costs as a way of solving the problem. Those companies that are far-sighted will look upon a CAD investment as one that will give them a very high return, rather than a cost they can't afford," Primrose explained.

The Cost of CAD

The type of CAD system a company can afford is more important now than it was in the past. Cost-cutting and budget-watching have taken a front seat to flashy features. According to Robert Kross, vice president of Autodesk's Manufacturing Division, "Companies look at a lower-cost solution in economies like this. There has been much more awareness of the engineers who hold the intellectual property of the company in their heads. Everyone believes that this year, we're going to see the economy blossom again. Companies are using the downtime to train more."

Companies with low-cost CAD products are finding it much easier to sell their software. Bob Mayer, executive vice president of sales and marketing for IMSI — which offers its TurboCAD V8 Professional program for just under $500 — believes that customers are getting the message that you don't have to spend a lot of money to get professional

(Continued on pg. 27)



LEWA Herbert Ott GmbH in Leonberg, Germany, used Solid Edge (an EDS PLM Solutions product) to design this pump and piping assembly.

functionality. "In the past, we had only one product that sold for $99, and the perception was that a $99 product couldn't have much functionality. Over time, we've raised the retail price by about $200 on that product, and most importantly, we put in the CAD functionality that CAD professionals expect," Mayer said.

Relatively new companies with new products face the challenge of competing both in pricing and in functionality with established "legacy" systems. "The economy, as far as who we're marketing to, hasn't changed," said Shaun Murphy, vice president of marketing for IronCAD. "There has to be a higher level of confidence before people will take their wallets out of their pockets. Since we're a new company and we just introduced our Innovation-Suite last October, we didn't need to make any adjustments. We brought it out value-priced and packaged for the price-conscious. Right from the beginning, we targeted our packaging, our products, and our pricing to the small- to medium-sized business," Murphy explained.

For the leading mid-range and high-end CAD vendors, it's more a question of whether customers can afford not to invest, according to Geoff Rogers, marketing manager of the Americas for IBM. "You have to look at the entire cost of what you're implementing. Look at the entire cost of what it's going to take to implement that solution, and then look at the benefits you'll receive therein. In this economic environment," Rogers said, "I think the question is not 'how can I afford to invest in product lifecycle management,' but, 'how can I afford *not* to invest in a product lifecycle management solution?'"

McEleney believes that when saving costs, companies need to look at how much they already have invested in a CAD system, and what they need to do with it. "In the large-scale enterprises," McEleney said, "they're not going to switch to a lower-cost alternative, because CAD costs are a small fraction of what the overall costs are."

PTC now offers the lowest-cost alternative — free downloadable software. Last month, the company introduced Pro/DESKTOP Express, a parametric, associative solid modeling program built on the same kernel as Pro/ENGINEER. According to Shepherd, the reasons for offering the free software were simple. "If you're a Pro/ENGINEER customer today, but you want to do business with a supplier who doesn't use Pro/E, that customer had a few-thousand-dollar barrier to get over to buy Pro/E. What if the person who doesn't use Pro/E could download an application for free from PTC.com that read in the Pro/E data because it's based on the same kernel?" The value proposition PTC is offering, said Shepherd, is that Pro/DESKTOP Express is a full-featured CAD system. "It's part of our game-changing strategy," he added. "In our industry, we're looking to turn things upside down."

The Migration Continues

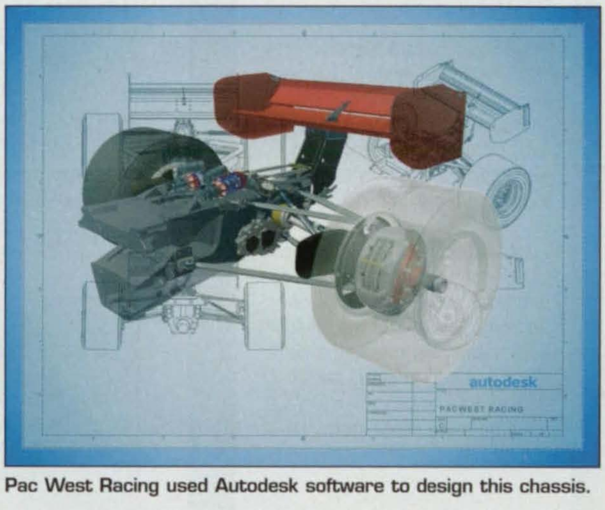
One of the issues facing CAD companies today also was a primary focus a year ago. Will 2D to 3D migration continue, and does widespread adoption of 3D CAD tools need to happen? This issue divided our experts more than any other aspect of the CAD market.

"In today's world, everybody already has a system. No one is starting with a drafting board and pencil anymore," said Kross. "We have a very large focus on 3D with Autodesk Inventor. Our objective is to shift our entire installed base to 3D." To that end, Autodesk has announced the Autodesk Inventor Series, which incorporates both 2D and 3D products — Autodesk Mechanical Desktop 6, based on AutoCAD, and Autodesk Inventor 5.3 3D design software. The new combined product allows users of AutoCAD, AutoCAD Mechanical, and Autodesk Mechanical Desktop to keep using their products while they get started with 3D by using Autodesk Inventor.

"Our customers get the advantage of keeping what they're using today, plus the new capability of a much easier to use product. Some customers will go gradually from 2D to 3D, but I hope we make it so easy for them, that they just say, 'I'm going to do this,'" said Kross.

"We see companies moving from 2D to 3D every day," said Rogers. "When you move to a 3D environment, you can immediately do things in maybe one step that used to take you five in a 2D environment, so you see immediate benefits." IBM offers the CATIA Companion, which allows companies to move into 3D without being intimidated. Rogers explained that CATIA Companion sits on the same workstation as CATIA. "When there is a specific topic on which you have a question when working in CATIA, you can enter into the Companion product, and it steps you through what you're trying to do in 3D."

According to Fischer, VX chose not to support either 2D or 3D, but to offer both. "In some circumstances, creating a quick drawing in 2D is sufficient. You can either work in the world of 3D or do it quick and dirty and get it done without style," he added. "Many 2D users don't ever have to use 3D. But if it needs to be part of an assembly, that must be created in 3D and exist as a digital model."



Pac West Racing used Autodesk software to design this chassis.

Primrose agrees that 2D will never entirely go away, but he sees 3D as the best choice. "There will always be people who refuse to move from 2D. They

might be able to make a drawing on the paper, but they get no benefit out of having a simple paper drawing. When it comes to changing designs, there is tremendous opportunity for errors if you don't have 3D."

Primrose also sees ease of use as a barrier to 3D that still exists. "Going forward, if you ask people what the most important attributes of a CAD system are, I don't think we — ourselves or our competitors — have come up with a radical change in usability. While we have lots of people talking about clever, cool features, the next thing is to come up with a whole new paradigm that will make CAD systems a whole generation easier to use."

Until that happens, 3D won't be the dominant technology, according to IronCAD's Murphy. "It's still probably a 2D design world," he predicted. "Do I believe 95 percent of people will be using 3D in the near future? No, I don't. It doesn't always make sense to use 3D," he added. "Many 2D users will tell you that the value they would get from moving to 3D is not worth the pain. You have a toolbox, and you pull out the right tool for the job. You wouldn't say, 'In the future, all repairs will be done with a hammer.' Design also has a bit of that, even though you don't have as many tools. There are certain tools you use because they are the best for the job. You have to make the call," Murphy said.

IBM, Autodesk, and SolidWorks have products designed specifically to help users move "painlessly" to 3D, which they feel will be the majority of the CAD world very soon. "I think 98 to 100 percent of people will use 3D tools. I think it needs to happen," said Kross. "If you make machines and you use 2D, and you're trying to compete with the machine maker down the street who's using 3D, you can't compete. He'll make a better machine he can understand better, and even more importantly, he can use his design data and product data in different ways — in his brochures, on his Web site."

Solo Golf used IBM's Product Lifecycle Management (PLM) solutions to design its new putter.

SolidWorks' McEleney agrees, but adds that the migration will happen more quickly than most think. "The fact is it won't happen this year, but it won't take ten years — I can tell you that. The world will move to 3D for a number of reasons, and the drivers behind it are simple," he said. "The average workforce is getting older, and as the older workers retire, today's graduates are the ones who grew up playing video games. They learned and work in a world based on 3D. As the older generation with a 2D legacy retire, the resistance level to 3D will come down."

Is a completely 3D world a better one? McEleney has mixed feelings about that. "The scary thing is as we adopt these 3D tools, are we going to lose any of the elegance and simplicity of engineering? As a vendor, I'm hard-pressed to fight that, because I think it's true. But it's a change for the better," he said. "If you look at the products manufactured today, they're all better because of 3D design tools."

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Proe Power Systems

Ericsson Cycle hot air engines produce power by externally heating one cylinder and cooling another. As the heated engine cylinder grows hotter, it requires more energy, which is wasted in the burner exhaust, reducing the overall engine-burner efficiency. Proe Power Systems' Afterburning Ericsson Cycle (AEC) engine recovers over 90% of the exhaust heat for higher thermodynamic efficiency, and has virtually no burner efficiency loss because there is no external burner. The AEC engine provides continuous combustion, obtaining the full heating value of any available fuel, including gasoline, methane, and propane.

The AEC engine is suitable for combined heat and power (CHP) and distributed power generation applications. It also can be used as a heat engine in hybrid vehicles, as a clean replacement for marine diesel engines, and as an auxiliary power source for the trucking industry to reduce noise and pollution from idling trucks.

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Aluminothermic Process Reduces Cost, Improves Yield for Chromium Metal Manufacturing

Devdutt Mohanty

Chromium is used extensively in the alloying of nonferrous metals like copper and aluminum. By itself, chromium is brittle, but when alloyed with other metals, a wide range of durable alloys can be produced. Using traditional methods such as the electrolytic process, chromium metals are expensive to produce. A new chromium manufacturing technology uses a proprietary process in which sodium dichromate is treated with acid and heated until sodium sulfate and chromic acid are separated. The chromic acid lumps that are left are finely ground, mixed with carbon black, fired, and converted to chromic oxide. This chromic oxide is passed through a process to produce 98% to 99% pure chromic oxide. This aluminothermic process does not use electricity for extraction, thus reducing production costs.

Get the complete report on this technology at:
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Biodegradable Plastic from Renewable Resources

Dr. Johan-Fredrik Selin, Development Manager, New Technology Business, Fortum

Conventional plastics are made from petrochemicals, which pose environmental disposal problems. A new biodegradable plastic is created using polylactides, an organic product formed by the fermentation of carbohydrates, which produces lactic acid. The lactic acid is transformed into a polymer, which breaks down into environmentally safe elements that are then completely metabolized by normal soil micoflora in a short period of time. Once exposed to light, humidity, oxygen, and soil microorganisms, polylactide plastics convert into humus, carbon dioxide, and water.

Manufacturers can use the same machinery currently used for traditional plastics to convert to the new polylactide plastic, and can use less energy compared to traditional hydrocarbon plastics.

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Hydrogen-Driven Actuators

Sachiko Matsuyama, Sensor Control Group, Ltd.

Actuators have a wide variety of applications including robotics, simulators, positioning systems, and opening devices. A new actuator absorbs and desorbs 1,000 times its own volume in hydrogen, creating gas pressure to drive the actuator. This actuator employs metal bellows lined with a metal-hydride (MH) alloy ranging in thickness from 3 to 10 mm. The alloy is then heated, causing it to release hydrogen, increasing gas pressure and extending the bellows. When the alloy is allowed to cool, hydrogen is absorbed, decreasing gas pressure and causing the bellows to contract.

A flexible polymer film that is currently being designed into an MH actuator for robotic applications might also be used to create artificial muscles for humans. Other applications include stabilizing earthquake-damaged structures, and as a lifter to move people and equipment in multi-story buildings.

Get the complete report on this technology at:
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Parallel-Processing High-Rate Digital Demodulator ASIC

CMOS circuitry can be used instead of more expensive analog circuitry or GaAs-based kind.

NASA's Jet Propulsion Laboratory, Pasadena, California

An all-digital demodulator has been developed for receiving radio signals with multigigahertz carrier frequencies phase-modulated with digital data signals at bit rates of hundreds of millions of bits per second. The phase modulation could be either binary phase-shift keying (BPSK) or quadrature phase-shift keying (QPSK), including QPSK employing bandwidth efficient pulse-shaping methods. The demodulator has been implemented in complementary metal oxide semiconductor (CMOS) application-specific integrated circuit (ASIC) configured to utilize algorithms that process signal data in multiple parallel streams.

The advantages of all-digital processing over traditional analog processing include greatly increased flexibility and reliability with reduced reproduction costs. Serial digital signal processing would entail processing rates so high as to necessitate the use of non-CMOS (e.g., GaAs-based) circuitry, which costs more and is more power-hungry, relative to CMOS. What makes it possible to implement the present ASIC in CMOS is the parallel-processing scheme, in which the number of parallel data streams is made large enough that the data rate in each stream is low enough to be within the capability of CMOS circuitry.

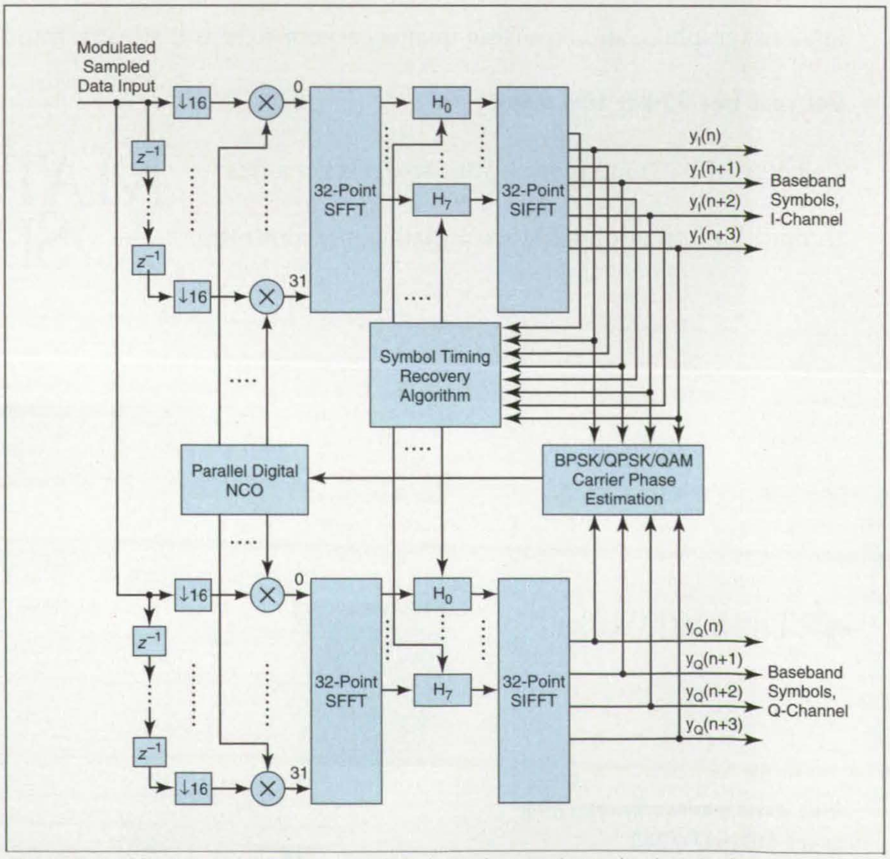
The present all-digital demodulator is characterized by an advanced parallel receiver (APRX) architecture (see figure), which replaces the receiver functions of the parallel receiver (PRX) architecture reported in "Parallel Digital Demodulators Using Multirate Filter Banks" (NPO-19620), *NASA Tech Briefs*, Vol. 20, No. 10 (October 1996), page 65. The APRX architecture is essentially one of time-varying frequency-domain detection filtering and symbol-timing correction.

Upstream of this demodulator, the received analog signal is converted to an intermediate frequency (IF) suitable for analog-to-digital (A/D) conversion, band-pass filtered, then digitized at a rate of 4 samples per symbol. The band-pass filtering rejects some noise and prevents the aliasing that would otherwise occur after A/D conversion. The digital signal is split into 32 parallel paths, decimated by 16 on each path, and digitally mixed on each path with a replica of the sampled IF carrier signal. The discrete Fourier transform (DFT) of the resulting 32 data points is then taken, via a specialized fast Fourier transform (SFFT), and multiplied by the one element of a bank of frequency-domain-matched filters. The correct matched filter is chosen by the closed-loop symbol timing recovery algorithm (see figure).

To suppress the double-frequency terms generated in mixing to baseband, low-pass filtering is performed, zeroing out the middle 16 components (which correspond to the high-frequency terms) in the frequency domain. Then the inverse discrete Fourier transform (IDFT) is computed, via the specialized inverse fast Fourier transform (SIFFT), and the middle 16 parallel outputs (which are unaliased and correspond to 4 symbol periods) are used for detection, tracking, and other purposes.

The foregoing process is repeated once every 16 cycles of the A/D-converter clock. The 16 points in the SIFFT output are 16 samples of a convolution of the input sequence with the matched-filter impulse-response function. Among these 16 samples are 4 baseband symbols that correspond to the peak signal-to-noise-ratio outputs of the matched filter.

Theoretical analysis, computational simulations, laboratory tests, and live satellite downlinks have shown that the error-rate performance of the APRX demodulator can be expected to be equivalent, and in some cases superior, to that of a conventional serial-processing digi-



The **APRX Architecture** provides for most digital signal processing to be done in the frequency domain. Here, "z^{-1}" denotes a digital sample delay, "↓16" signifies decimation by a factor of 16, and H_i denotes a complex time-varying matched/detection filter bank that also performs the functions of low-pass digital filter and symbol timing recovery.

tal receiver. In comparison with the PRX architecture, the APRX architecture can be implemented with significantly reduced complexity. In comparison with traditional serial digital receivers, the APRX demodulator ASIC can process much higher data rates. The next generation implementation of the APRX ASIC is currently being developed to process higher order modulations and data rates in excess of 2 billion bits per second.

This work was done by Parminder Ghuman, Scott Hoy, and Gerald Grebowsky of Goddard Space Flight Center and Andrew Gray and Meera Srinivasan of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*
NPO-21230

Reusable Software for Autonomous Diagnosis of Complex Systems

Software incorporates advances in several data analysis disciplines to enable autonomous self-monitoring.

NASA's Jet Propulsion Laboratory, Pasadena, California

A software system designed to provide a purely signal-based diagnosis of virtually any time-varying system has been developed. This software is part of an overall concept called "Beacon-based Exception Analysis for Multimissions," or BEAM. This concept provides for real-time autonomous diagnostics and prognostics of virtually any complex system (e.g., intelligent spacecraft or advanced aircraft) by use of software executed on an embedded computer.

BEAM provides for the onboard identification and isolation of anomalous conditions, making it unnecessary to telemeter large quantities of raw data for analysis on the ground. BEAM thereby reduces operator or pilot workload by isolating all anomalies that could affect safety, navigation, or performance. BEAM was conceived as an incrementable autonomy technology, capable of operating with no human intervention but also supplying condensed information to aid human operating decisions. Thus, the system is useful at both extremes, viz, total autonomy and complete operator control, and at every level in between.

This particular component of BEAM, called the System Invariant Estimator (SIE), uses strictly signal-processing methods and is therefore highly reusable. Many approaches to the problem of self-diagnosis exist, such as model-based and neural network solu-

tions. However, in many cases these approaches require significant investment in modeling and training, perform poorly beyond the model or training envelopes, and perform poorly in the presence of data uncertainty. Because of BEAM's underlying architectural differences from these approaches, a priori modeling is useful but not necessary, the training process is relatively simple and is incrementable, and the system is capable of correctly isolating anomalies well outside the training envelope.

The SIE provides a standard method for real-time fusion and analysis of all time-varying system observables, including sensor data as well as derived quantities and certain quantifiable software indications. These data sources can be from similar sensors or from radically varying types. The intermediate information products of the SIE retain considerable physical meaning, which allows complete traceability of the diagnostic state and reconstruction of the BEAM conclusions. The SIE provides detection capability, in both space (signal localization) and time, for both sudden and gradual changes in any system. The approach is readily scalable to systems of higher complexity and is resistant to the usual problem of combinatoric explosion as system size increases.

The SIE functions by considering the cobehavior of time-varying quantities, in particular their dynamics, as sensed from an operating system. Suitable sensors are widely used and typically include so-called performance sensors, i.e., temperatures, pressures, and the like. Certain repeatable relationships between physical quantities, and, hence, sensor values, exist in the system as dictated by the physics of its operation. These relationships are repeatable and relatively insensitive to changes in the environment or normal fluctuations.

The SIE constructs a single quantitative object to capture this cobehavior across the entire system or subsystem. This object reflects both known relationships, such as voltage/current relationships that are easily modeled, and unknown relationships, such as thermal transmission through system structure that is not well understood. The object is studied with respect to stability, for the purpose of detecting instantaneous changes or mode switches, and its long-term convergence, which reveals the presence of incipient faults, degradations, or minor and local shifts away from desired performance. This allows us to consider the entire space of faults, including those for which model information or even data is not available.

The SIE is a computationally efficient calculation grounded entirely in signal theory. It is trained using raw sensor data during known nominal operation, i.e., "supervised" training. This data would ideally cover all nominal modes. However, should this be impossible to obtain, or if only approximate data is available, the SIE can be executed in a learning mode. This is possible because the SIE is capable of capturing "novel" data as part of its anomaly detection, and should this data prove to be acceptable upon review, it can be incrementally added to the SIE training. The only needed human effort is providence of nominal data; all other training and detection is completely autonomous.

The SIE can accept time-correlated input data from relatively large sources. Its specific outputs are the presence of off-nominal behavior or degradation, the signals implicated in the fault, and a predictive assessment of loss of functionality. It also identifies specific pair-wise resonances contributing to the fault (critical for assessing control-loop-induced failures), renormalization functions to quantify intramodal stability and degradation, and capture of off-nominal

flight data to allow adaptation to new modes or specific hardware.

Unlike similar neural network approaches, each information product of BEAM has an implicit physical meaning. Where uncertainties about the diagnosis exist, each step towards constructing the ISE (information space estimate) and its analysis can be performed individually. This provides operators the maximum utility in managing system information. This property also allows BEAM to optimally summarize fault information for downlink.

The present software has been applied to a broad variety of systems and has demonstrated enormous potential in improving system operability while reducing operator workload. Systems previously studied have spanned from 6 to 1,600 observables, and at various data rates from 0.016 Hz to 10 kHz.

This work was done by Sandeep Gulati and Ryan Mackey of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Intellectual Property group
JPL
Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-20803, volume and number of this NASA Tech Briefs *issue, and the page number.*

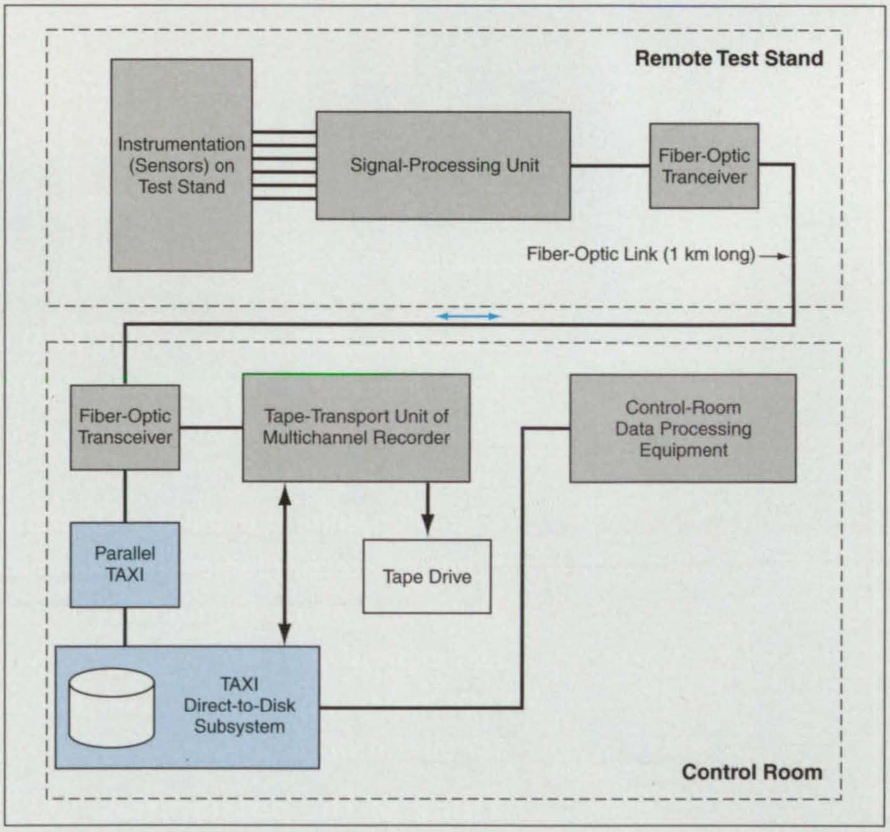
TAXI Direct-to-Disk Interface Demultiplexes Proprietarily Formatted Data

Data can be stored in channel files in a PC in real time.

Stennis Space Center, Mississippi

The TAXI Direct-to-Disk interface is a special-purpose interface circuit for demultiplexing of data from a Racal Storeplex (or equivalent) multichannel recorder onto one or more hard disks that reside in, and/or are controlled by, a personal computer (PC). [The name "TAXI" as used here is derived from the acronym TAXI, which signifies transparent asynchronous transceiver interface.] The TAXI Direct-to-Disk interface was developed for original use in capturing data from instrumentation on a test stand in a NASA rocket-testing facility. The control, data-recording, and data-postprocessing equipment of the facility are located in a control room at a safe distance from the test stand. Heretofore, the transfer of data from the instrumentation to the postprocessing equipment has entailed post-test downloading via software, requiring many hours to days of post-test reduction before the data could be viewed in a channelized format. The installation of the TAXI Direct-to-Disk interface, in conjunction with other modifications, causes the transfer of data to take place in real time, so that the data are immediately available for review during or after the test.

The instrumentation is connected to the input terminals of the signal-processing unit of multichannel recorder by standard coaxial cables. The coaxial output of the signal-processing unit is converted to fiber-optic output by means of a commercial coaxial-cable/fiber-optic converter (that is, a fiber-optic transceiver) designed specifically for this application. The fiber-optic link carries the data signals to an identical fiber-optic transceiver in the control room. On the way to the TAXI Direct-to-Disk interface that is the focus of this article, the data signals are processed through a companion special-purpose circuit denoted by the similar name "parallel TAXI interface" (see figure).



The **Data-Flow Architecture** of the modified test-data-handling system of a rocket-testing facility includes the parallel TAXI Direct-to-Disk interface and the TAXI-100 Direct-to-Disk interface solution.

The TAXI Direct-to-Disk interface is implemented by means of field-programmable gate arrays (FPGAs), memory chips, and other integrated circuits on a printed-circuit board that conforms to the peripheral component interface (PCI) standard and is denoted the TAXI-100 card. The TAXI-100 card performs real-time demultiplexing of the data signals from the parallel TAXI Direct-to-Disk interface to individual chan-

nel files within the host PC. The data are provided in a layered interface that consists of the TAXI physical layer with the Racal proprietary data format contained in the application layer. The application layer is stripped off by the parallel TAXI Direct-to-Disk interface. Parallel clock and data signals containing the Racal proprietary data format are received by the TAXI-100 card in the parallel format and demultiplexed, according to formats extracted from within the data, into channel buffers in the form of first-in/first-out (FIFO) memory chips. Other proprietary programmable logic chips provide for the management and buffering of the channel blocks until they are presented to the host PC across a PCI bus interface. Real-time software drivers running under the Microsoft NT 4.0 operating system provide for real-time handling of interrupts and buffering onto small computer systems interface (SCSI) disks in individual channel files. A host graphical user interface enables the user to select recorder channels.

This work was done by Bruce G. Newnan of Integrated Systems Consultants and Steven F. Ahlport of Pacific Custom Systems, Inc., for **Stennis Space Center.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Integrated Systems Consultants
1282 Shasta Ave.
Suite 1
San Jose, CA 95126

Refer to SSC-00141, volume and number of this NASA Tech Briefs *issue, and the page number.*

Program Improves Transfer of Data From CAD to Machine Shops

Lyndon B. Johnson Space Center, Houston, Texas

The EMNet computer program has been developed to overcome the difficulties and reduce the errors that, heretofore, have been encountered in transferring data from computer-aided design (CAD) systems to computer numerically controlled (CNC) machines. EMNet could improve operations in almost any industrial machine shop that uses CNC equipment.

The difficulties and errors in question arise because CNC output files (files of numerical control data generated by CAD postprocessing programs) have customarily been transferred either by use of floppy disks or by manual entry of data into CNC equipment. Sometimes these files are too large to fit on floppy disks. Even when floppy disks are used, data transfers often fail. Moreover, although some programs for transfer of data from CAD to CNC operations have been commercially available, those programs are expensive, are usable only by persons who have advanced computer skills, and have caused failures of computer networks.

EMNet was designed for use by machinists who have little or no computer experience and are responsible for entering numerical control data into CNC machinery, as needed, to produce machined parts. EMNet features an easy-to-use "point and click" graphical user interface, and is available in versions for the Windows 3.x, Windows 95, and Windows NT operating systems. EMNet offers a full complement of Windows-style help displays for both machinists and computer-workstation administrators.

A computer on which EMNet is executed communicates with CNC machines via RS-232 serial interfaces connected according to specifications of the manufacturers of the machines. EMNet is easily configurable, and can be executed on a personal computer connected to two CNC machines. Each CNC machine can be assigned a name, a communication port, a default directory for data files, and options for whether to transmit carriage returns, line feeds, or end-of-block characters to the machine. If two machines are connected to a computer, the communication protocol for each port can be configured for the corresponding machine, separately from the protocol for the other port and its machine. Both the machine options and the communication-port settings are protected by a password that can be changed by a computer-workstation administrator.

After EMNet has been configured, the interaction required by the machinist is minimal. To transmit numerical control data to a CNC machine, the machinist performs the following steps:

1. Choose the machine by use of front-panel option buttons in an EMNet display. EMNet automatically switches to the default directory for the machine and opens the respective communication port.

2. Click the "File" button on the EMNet display and select the file to transfer.
3. Prepare the CNC machine to receive the file.
4. Click the EMNet "Send" button.

To receive numerical control data from a CNC machine by use of EMNet, the machinist performs the following steps:

1. Choose "Settings," "Transfer," "Receive" from the EMNet menu.
2. Click the "Receive" button.
3. Send the data from the control panel of the CNC machine.

EMNet also offers the capability of performing a byte-by-byte comparison of two numerical-control-data files. This capability was added to ensure that the data received by a CNC machine are intact; that is, without errors or missing bytes. To initiate a byte-by-byte comparison, the machinist performs the following steps:

1. Choose "File," "Compare" from the EMNet menu.
2. Select the "known good" (original) file.
3. Select the file to compare (typically, a file transferred from a CNC machine back to the computer).
4. Verify whether the CNC machine includes a "program number" in the downloaded data, and if so, the line where the program number resides (typically line 2).

EMNet then performs a byte-by-byte comparison of the two files and displays the results. If a data mismatch is encountered, the comparison is terminated and the line and byte location of the mismatch is displayed.

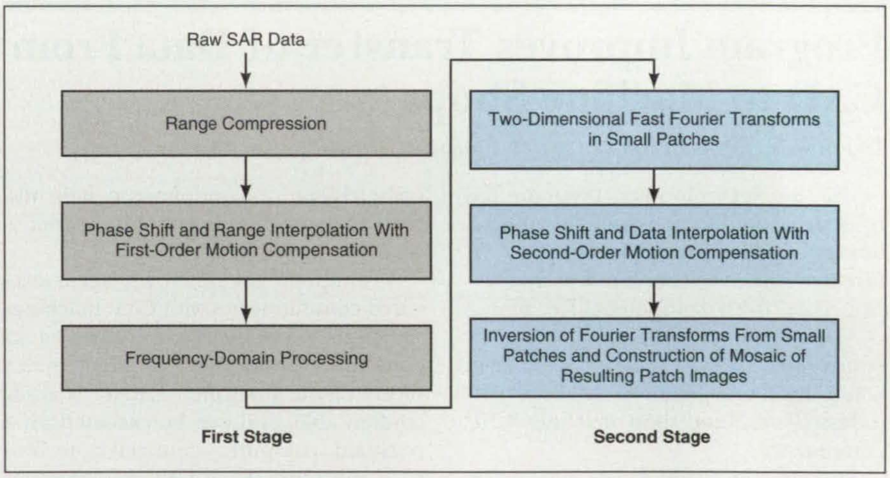
This work was done by W. David Smith of Rothe Joint Venture, L. P., for **Johnson Space Center**. *For further information, contact the Johnson Technology Commercialization Office at (281) 483-3309.*
MSC-22986

Compensating for Motion Errors in UWB SAR Data

Processing is implemented in two stages by a computationally efficient algorithm.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of processing data acquired by ultra-wide-band (UWB) synthetic-aperture radar (SAR) provides for suppression of those errors that are caused by the undesired relative motion of the radar platform and the targets. This method involves, among other things, processing of data in the wave-number or frequency domain and the application of motion compensation as a function of the positions of a target relative to the radar platform.



Motion Compensation to first order is effected for a data strip, then refined to second order over small overlapping constituent patches. A motion-compensated image of the large patch is then constructed as a mosaic of the images of the smaller patches.

The need for this method arises because of two sources of complication in UWB SAR that are not present in narrow-band SAR. One source of complication is that the prior commonly used SAR motion-compensation algorithm depends upon the Doppler shift of a well-defined radar-signal frequency, but the signal frequency in UWB radar is not well defined. The other complication is that the prior motion-compensation algorithm depends on azimuthal narrowness of the radar beam, but in UWB SAR, the requirement to make the range and azimuth resolutions approximately equal translates to a requirement that the radar beam be azimuthally wide (typical width of the order of a radian).

In a wide-beam SAR system, the key dilemma in properly compensating for motion is that one needs to track the location of each target on an SAR strip map, but the locations of the targets are not known from the outset. The present method addresses this dilemma. The method involves two stages of processing (see figure).

In the first stage, a strip parallel to the flight track is processed and targets are motion compensated, assuming that they are located in the antenna fan beam plane. Following the first-order motion compensation, a frequency-domain SAR processing algorithm is applied. The motion compensation for targets in off-boresight directions is not correct, but the motion compensation for the target(s) in the nominal center of the beam is correct. This stage of processing ensures that target impulse responses are located correctly geometrically, albeit insufficiently focused.

In the second stage of processing, the data strip is divided into overlapping small patches and it is pretended that the target(s) in each small patch lie at the center of the patch. The data processed in stage 1 are reprocessed within each small patch to refine the motion compensation. This reprocessing includes second-order motion compensation that takes the form of frequency and phase shifts applied to the partially motion-compensated UWB SAR data. Inasmuch as the motion compensation is perfect only at the center of each small patch, the smaller the patches, the better the motion-compensation performance. For the sake of computational efficiency, the two-stage processing algorithm has been formulated such that the reprocessing in small patches is much less computationally demanding than is the processing of the wide area patch, such that it is computationally affordable to reprocess many small patches.

This work was done by Soren Madsen of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*
NPO-21096

Program for International-Temperature-Scale Calculations

A computer program implements several aspects of the International Temperature Scale of 1990 (ITS90).

- For platinum resistance thermometers (PRTs), the program can perform reference-function (W_{ref}) calculations traceable to the National Institute of Standards and Technology (NIST) through its Technical Note 1265. W_{ref} represents a perfect PRT that has a resistance of exactly 1 Ω at the triple-point temperature of water. The program provides for the entry of coefficients generated by a calibration facility and converts a measured resistance to an equivalent temperature with an accuracy of 5 millikelvins. The program also performs measurement calculations for PRTs: In such a calculation, the triple-point temperature of water as determined by a calibration laboratory is multiplied by the applicable NIST reference value.
- The program converts between output voltages and temperatures for several types of thermocouples that yield measurements traceable to NIST through its Monograph 175. These thermocouples are of types T (Cu/Cu-Ni), K (Ni-Cr/Ni-Al), J (Fe/Cu-Ni), E (Ni-Cr/Cu-Ni), N (Ni-Cr-Si/Ni-Si-Mg), B [Pt(30 percent)-Rh/Pt(6 percent)-Rh], S [Pt(10 percent)-Rh/Pt], and R [Pt(13 percent)-Rh/Pt].

This program was written by Richard T. Deyoe of Dynacs, Inc., for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

KSC-12166

Updated Global Atmospheric Reference Model Computer Programs

The 1999 version of the NASA/Marshall Space Flight Center Global Reference Atmospheric Model (GRAM-99) and version 3.8 of the Mars Global Reference Atmospheric Model (Mars-GRAM) are the latest in two series of computer programs for calculating selected physical properties of the atmospheres of Earth and Mars, respectively. GRAM-99, like prior versions of GRAM, implements an amalgamation of empirical models that represent geographical, seasonal, and monthly variations of the state of the terrestrial atmosphere (thermodynamic variables and horizontal and vertical wind components) at all altitudes from the ground up to those of spacecraft orbits. Mars-GRAM provides engineering estimates of density, temperature, pressure, and wind components in the Martian atmosphere as functions of latitude, longitude, altitude, and time.

The 1995 version of GRAM (GRAM-95) and the underlying model were described in "NASA/MSFC Global Reference Atmospheric Model — 1995 Version" (MFS-31105) *NASA Tech Briefs*, Vol. 21, No. 3 (March 1997), page 68. For altitudes from 0 to 27 km, GRAM-99 utilizes either of two sets of data: the binary-formatted Global Upper Air Climatic Atlas (GUACA) [which was also used in GRAM-95] or the newer ASCII-formatted Global Gridded Upper Air Statistics (GGUAS). For altitudes from 20 to 120 km, GRAM-99 uses, as did GRAM-95, a specially developed set of data based on Middle Atmosphere Program (MAP) data. Above 90 km, GRAM-99 uses the 1999 version of the Marshall Engineering Thermosphere (MET) model [also known as the Jacchia model]. Fairing techniques assure smooth transitions among the models and sets of data in the overlap height ranges of 20 to 27 km and 90 to 120 km.

Like GRAM-95, GRAM-99 estimates concentrations of water vapor and of O_3, N_2O, CO, CH_4, CO_2, N_2, O_2, O, A, He, and H. For altitudes above 90 km, the Jacchia model can also provide concentrations of N_2, O_2, O, A, He, and H. Atmospheric-constituent profiles of the Air Force Geophysics Laboratory are also used extensively for altitudes up to 120 km.

GRAM-95 incorporated a then new variable-scale perturbation model that provides both large-scale (wave) and small-scale (stochastic) deviations from mean values for thermodynamic variables and horizontal and vertical wind components. Such perturbations are characterized by time scales of less than a month and are associated with turbulence, storms, atmospheric tides, and other phenomena. GRAM-99 incorporates improvements in the small-scale perturbation model for representing intermittent phenomena.

A major new feature in GRAM-99 is an option to substitute Range Reference Atmosphere (RRA) data for conventional GRAM climatological data when a trajectory passes sufficiently near any RRA site. This feature makes it possible, for example, to simulate the atmosphere, starting from takeoff at one RRA site (e.g., Edwards Air Force Base), where RRA data are used, then make a smooth transition to an atmosphere characterized by GRAM climatology en route, then make another smooth transition to an atmosphere characterized by RRA data at a landing site (e.g., White Sands, New Mexico).

A complete user's guide for running GRAM-99 is available. The user's guide includes sample input and output. Also included is an example that shows how to incorporate GRAM-99 as a subroutine in another program (e.g., a trajectory code).

Mars-GRAM implements a mathematical model based on surface and atmospheric measurements taken during the Mariner and Viking (orbiter and lander) missions. At altitudes above about 120 km, the Mars-GRAM model is based on the Stewart (1987) Mars thermospheric model. Mars-GRAM can be used as a stand-alone program or can be incorporated into an orbit-propagator or trajectory code.

Version 3.8 of Mars-GRAM incorporates some new features that were suggested by users engaged in the design and operation of spacecraft on missions of robotic exploration of Mars. Mars-GRAM 3.8 uses new values of planetary reference ellipsoid radii, gravitation terms, and the rate of rotation, (consistent values now used by NASA's Jet Propulsion Laboratory), and includes centrifugal effects on gravity. The model now uses the NASA Ames Global Circulation Model low-resolution topography. Curvature corrections are applied to winds, and limits based on speed of sound are applied. The altitude and molecular weight of the ionization peak of the F1 layer of the Martian ionosphere and the density scale height (including the effects of the change of molecular weight with altitude) are computed. A check is performed to dis-

allow temperatures below the sublimation temperature of CO_2.

The user's guide for Mars-GRAM 3.8 summarizes the changes made for this version and includes an appendix that summarizes changes made for versions 3.5 through 3.7. It includes instructions for running the program, plus sample input and output files.

These programs were written by Carl G. Justus of Computer Sciences Corp. for **Marshall Space Flight Center**. *For further information, contact Carl G. Justus at Jere.Justus @msfc.nasa.gov.*
MFS-31461/62

Gyroscope Automated Testbed

The Gyroscope Automated Testbed (GAT) is a fully automated inertial device characterization testbed. Rotational response parameterization and short-term noise stability analysis are the fundamental principles behind the system. Complete response characterization, bias stability, sensitivity, and range are supported along with a drift stability and noise analysis through use of a Green chart and calculation of the power spectral density. GAT is also capable of performing turn-on cycle stability and temperature-dependent testing.

The system is fully automated yet allows complete customization of test parameters. Each of the specific tests may be enabled or disabled as desired, and each test may be individually configured. The state of the system can be saved and loaded at any time providing quick and easy access to various configurations.

The hardware interface layer of the program has been abstracted to provide a flexible yet robust method of input and control. The data-acquisition subsystem provides a universal method of acquiring data from devices. Direct analog inputs are provided and can be individually customized. General-purpose-interface-bus-(GPIB-) compliant devices may be used for either input (i.e., voltmeters) or as control or output (i.e., temperature controller). This flexible arrangement allows nearly unlimited expandability and extendibility to future capabilities. An abstract rate table interface permits control of any rate table which supports an analog or GPIB interface.

Results are presented in both summary and complete form. Processed and raw data can be saved to a file during a test. Key values and data plots are output to a table in real time during a test. At the completion of a testing session, a document is automatically generated which summarizes the results and encapsulates all output charts generated during the session.

The GAT system provides a cost-effective way of characterizing inertial devices. Although designed for analyzing microelectromechanical (MEM) vibratory gyroscopes, it can easily be adapted to accelerometers by simply changing the units of measure. It is also highly efficient as up to five devices can be tested simultaneously.

The GAT system currently is executed on a Pentium III (or equivalent), 550-MHz computer with 256MB of RAM, 10GB hard drive, internal data acquisition card, and GPIB interface card.

This program was written by Christopher Evans and Roman Gutierrez of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20847.

March 2002

PHOTONICS Tech Briefs

PHOTONICS SOLUTIONS FOR THE DESIGN ENGINEER

Cover photo courtesy Point Source Inc.

www.ptbmagazine.com

Photonics Tech Briefs 2001 Readers' Choice Product of the Year

Each issue of *Photonics Tech Briefs* in the year 2001 carried a Product of the Month, a photonics product the editors felt was of special interest and value to readers who work with lasers, optics, fiber optics, and video and imaging equipment. The winners of the gold, silver, and bronze awards, described in detail below, were chosen by readers voting for one of these products on *Photonics Tech Briefs'* web site earlier this year. The 2001 winners are:

★ **Gold Winner and Product of the Year:** TNP Instruments (Carson, CA) Model DUV-250 deep-UV microscope;

★ **Silver Winner:** Raytheon Commercial Infrared (Dallas, TX) PalmIR digital thermal imaging camera; and

★ **Bronze Winner:** Polytec PI (Tustin, CA) F-130 nanoalignment system for photonics packaging.

TNP Instruments DUV-250 Deep-UV Microscope

TNP Instruments calls its DUV-250 deep-UV microscopic imaging system the first ever to combine microscopic resolution below one-quarter micron with real-time operation. The DUV-250 takes advantage of TNP's exclusive advancements in optics and broadband mercury arc lamp illumination to achieve 25,000× magnification. Another benefit, the company says, is significantly reduced cost: the DUV-250 typically operates at less than half the cost of traditional laser systems. Designed to fill a gap between visible-light and scanning electron microscopy, the company says, it represents a major innovation for semiconductor premanufacturing and failure analysis, for medical research and testing, for photomask inspection, and for mass storage component manufacturing.

TNP Instruments DUV-250 Deep-UV Microscope

Another advantage of the high magnification of this microscope is that even submicron features can be checked without any sample preparation. It can produce useful images of features 0.1 micron and below.

www.tnpinstruments.com

Raytheon Commercial Infrared PalmIR 250 Digital Thermal Imaging Camera

Raytheon Commercial Infrared says that its PalmIR 250 handheld digital thermal imaging camera is the first with zoom capacity. It produces detailed 320-×-240-pixel uncooled ferroelectric thermal images, and offers users a choice between the standard 75-mm f/1.0 lens package or other packages ranging from 25 to 150 mm. An electronic zoom (2×) and expanded menu items, including video peaking, are also standard. It weighs only 2.6 pounds, and is operational with only one hand.

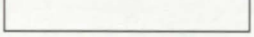
The PalmIR 250 offers VCR-compatible video output through an RCA jack in an NTSC format, and PAL format for international customers. Raytheon Commercial Infrared expects the camera to find applications in public safety, search and rescue, surveillance, industry, and wildland and exterior firefighting. With the zoom capacity, users can both see through darkness up close and also spot a person or an object up to 2400 feet away. With its sharp picture and portable design, the PalmIR 250 is effective for day and night surveillance to monitor perimeters, scan long distances, and spot intruders. In industrial applications, the unit can be used for predictive maintenance to inspect machines, electrical conduits, and pipelines for excess heat, leaks, or potential failures.

Raytheon Commercial Infrared PalmIR Digital Thermal Imaging System

www.raytheoninfrared.com

Polytec PI F-130 Nanoalignment System for Photonics Packaging

Polytec PI Inc. is marketing the F-130 X-Y-Z nanopositioning system for photonics packaging, originating from its German partner Physik Instrumente. The F-130 combines a 15-×-15-×-15-mm motor-driven travel range with what the company calls ultra-precision piezonanopositioning technology and nanometric-scale resolution. It also has a 100-×-100-×-100-micrometer high-speed piezoelectric travel range for fine alignment. Resolution of the motor is 0.1 micrometer and of the piezoelectric drive 1 nanometer. Other features are fast scanning speed, quick settling, small dimensions, and closed-loop option with either the motor or piezoelectric drive.



Polytec PI NanoAlignment System for Photonics

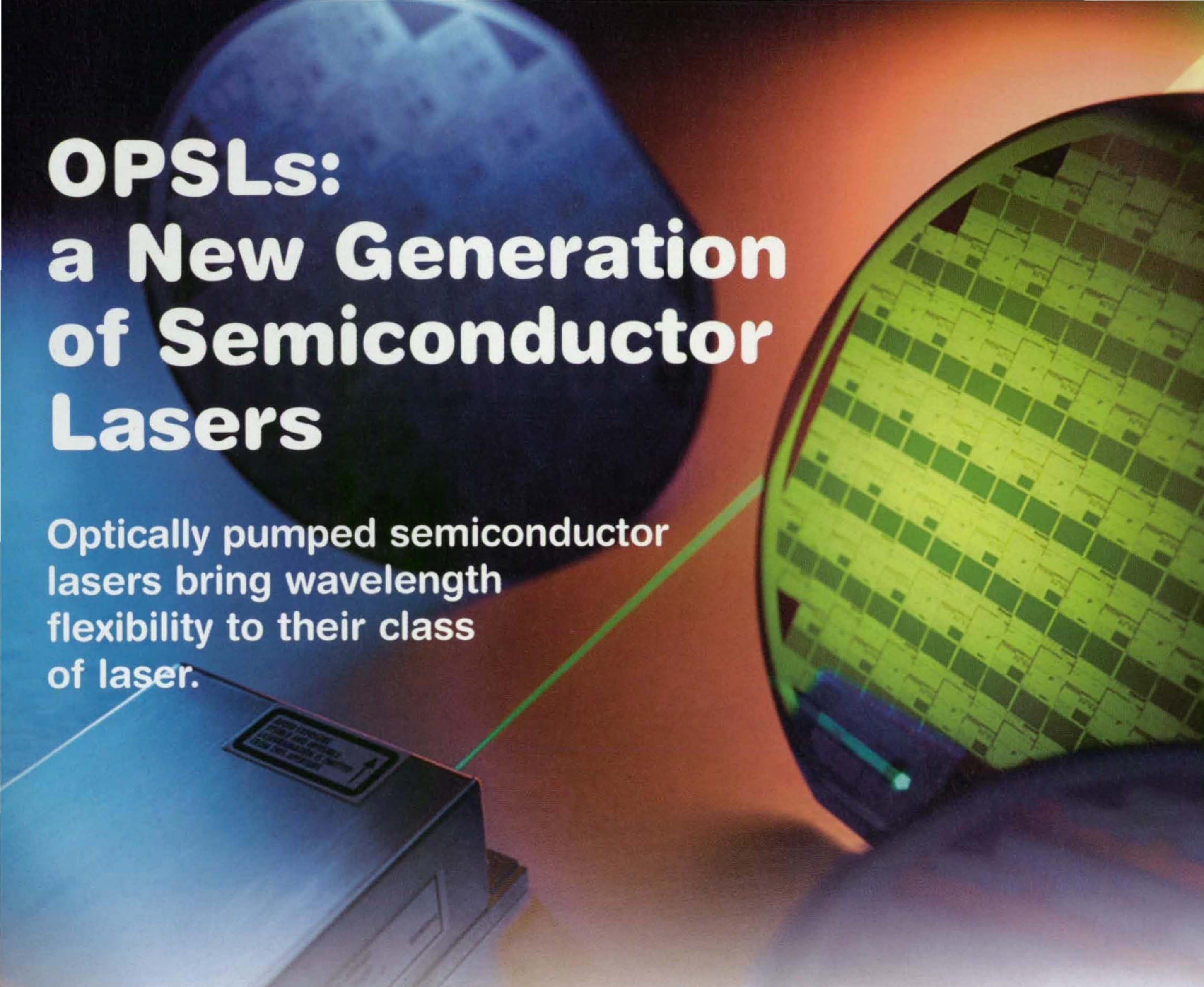
Designed for fiber positioning and photonics packaging applications, the F-130 has a large selection of control electronics for easy adaptation. A 2D transverse profile of a single-mode fiber coupling can be acquired in less than four seconds.

Polytec sees typical applications in fiber alignment, semiconductor technology, mass storage, optical instrumentation, and more.

www.polytecpi.com

OPSLs: a New Generation of Semiconductor Lasers

Optically pumped semiconductor lasers bring wavelength flexibility to their class of laser.



Laser instrumentation and equipment designers have traditionally been challenged by a combination of wavelength and integration limitations. While trying to develop compact, flexible instruments for contemporary end-user requirements, designers have sought to leverage the power of diode-pumped solid-state lasers in applications that traditionally employed larger and less efficient air-cooled argon ion lasers. In existing diode-pumped lasers that used neodymium-doped crystals, designers found the compact size and efficiency they needed but also found huge gaps of "no-man's land" in the wavelength scale, especially in the blue. Furthermore, the advent of violet laser diodes still did not fill gaps in the blue-green segments of the spectrum. A new generation of semiconductor lasers, namely optically pumped semiconductor lasers (OPSLs), addresses designer and market wavelength issues while facilitating compact packaging and efficiency that opens new opportunities for laser-based instruments.

Optically pumped semiconductor lasers are part of a class of devices called vertical external-cavity surface-emitting lasers (VECSELs). The OPSL implementation is based on a patented technology from Coherent that uses this technology in its sapphire laser product line. Most VECSELs are driven by electrical current, as are standard diode lasers. In contrast, the OPSL uses optical pumping to drive the laser emission. This provides an excellent spatial mode quality that electrical pumping cannot offer.

The main building blocks for an OPSL include a continuous-wave 808-nm semiconductor pump laser, identical to those used for pumping Nd:YAG or Nd:YVO_4 diode-pumped solid-state lasers; focusing optics; the optically pumped semiconductor (OPS) chip that acts as a gain medium and high reflector; and an output coupler. Figure 1 is a schematic of this arrangement.

The enabling technology is the GaAs OPS chip, grown using molecular beam epitaxy (MBE), the process well known for wafer manufacturing consistency (see Figure 2). The lower section of the OPS chip consists of several epitaxially grown high- and low-index layers that form a distributed Bragg reflector, which serves as the OPSL's rear cavity mirror. Several planar quantum wells, designed to emit at the desired wavelength, are grown on top of the index layers. Cladding layers separate the emission quantum wells and absorb the pump photons. The top layer of the OPS chip is given an antireflection coating.

Leveraging extensive GaAs knowledge accrued over time in the semiconductor industry, the OPS chip is fabricated using the same standard GaAs-based material and MBE wafer growth as DPSS pump diodes. The technology also gives the precise control over epitaxial growth made possible by the MBE method. In addition, the intracavity second harmonic generation (SHG) method, used extensively in fabricating existing Nd:YAG and Nd:YVO_4 DPSS product lines, is also used in OPSL fabrication.

OPSL fabrication uses the proprietary Permalign™ process, a high-

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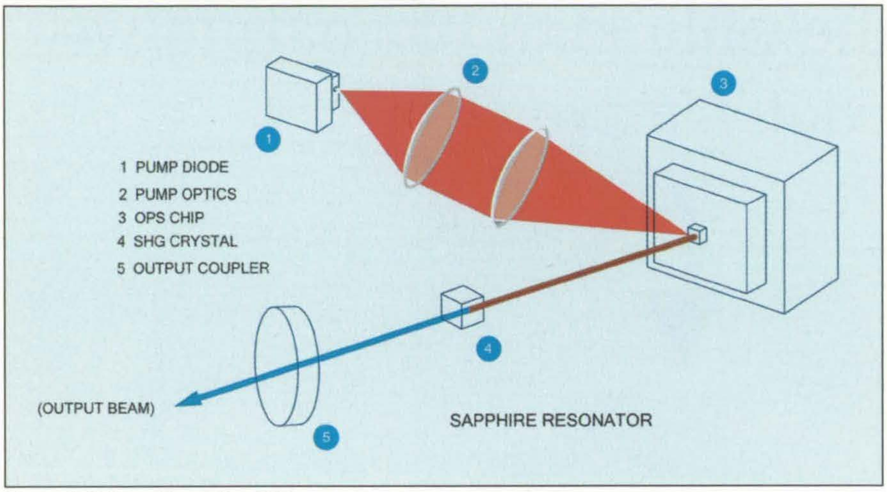

Figure 1. Schematic of the OPSL.

volume clean-room manufacturing method. This method uses robotics to accurately align optical components while permanently soldering or welding each into place. The laser cavity is then hermetically sealed for environmental stability and long lifetime with no user intervention.

The design significance of the OPSL technology is that, for the first time, wavelengths can be developed to the specifications of an OEM application. This is because OPSL wavelengths can be engineered simply by varying the semiconductor growth, unlike DPSS lasers, where the fundamental wavelength is defined by fixed atomic transitions. OPSLs can also be easily designed with high intracavity powers, making them ideal for intracavity frequency doubling.

Freeing the designer of wavelength gaps and limitations, this technology facilitates the flexibility for OPSL development at several wavelengths in the IR and blue at powers ranging from tens of milliwatts to multiple watts.

OEM Integration Advantages

The solid-state foundation and power efficiencies of the OPSL have spawned new possibilities for OEM instrumentation integration and packaging. The laser head itself measures less than three inches by five inches. This compact form factor permits deep integration in instrumentation, bringing the laser source nearer to samples or work surfaces. Supplanting bulky and inefficient air-cooled argon ion lasers, OPSL technology integration can shrink a large instrumentation package down to a simpler and more cost-effective tabletop format that requires no supplemental cooling for the laser source. For some applications, this represents a significant reduction in instrument footprint.

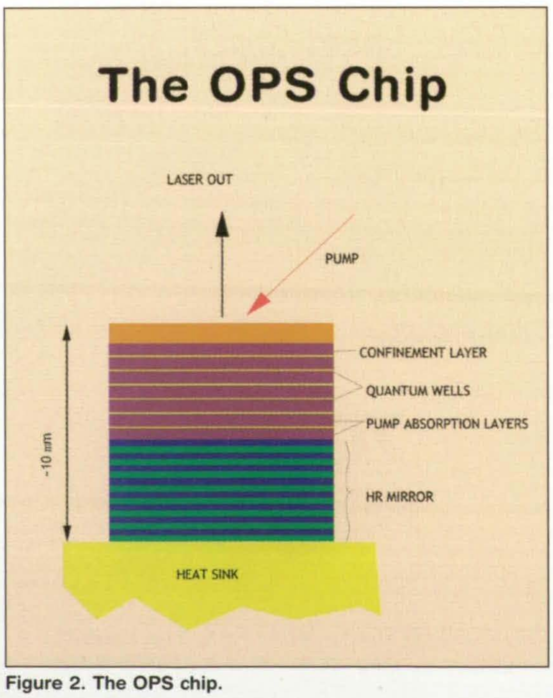

Figure 2. The OPS chip.

The Coherent OPSL technology can dramatically reduce a design's power and heat dissipation requirements. For example, the 488-nm laser draws a maximum of 60 W of electrical power, up to 50 W of which goes to the thermoelectric cooler to stabilize the resonator independently of the environmental conditions. The remaining 10 W is used to generate blue output. By comparison, the earlier air-cooled argon ion laser requires at least 1.5 kW of power. Typically the OPSL designs consume 98 percent less power, with 98 percent lower heat dissipation requirements, which represents a much-needed breakthrough in efficiency.

With the trend in laboratory and research management moving toward populating laboratories with ever-increasing numbers of analytical instruments, product design efficiency and compact packaging become critical. Compact instrumentation based on OPSL technology can be deployed in clustered environments without the heat dissipation or ambient cooling fan noise problems that argon-ion-laser-equipped instruments would generate. Thus energy is conserved and ergonomic issues are minimized.

OPSLs are available today that produce 10 to 20 mW at 460 nm and 488 nm with very low noise (less than 0.25 percent RMS) and TEM_{00} spatial characteristics with an M^2 of less than 1.1. These factors improve signal-to-noise ratios, sensitivities, and focus properties, which are key for OEM designs to meet end-user application demands.

Wavelength Independence Spurs Growth

Customization for wavelength requirements is now the response to market and application pressures. Products at 488 nm, 460 nm, and 980 nm have been commercialized. So far, the 488-nm laser

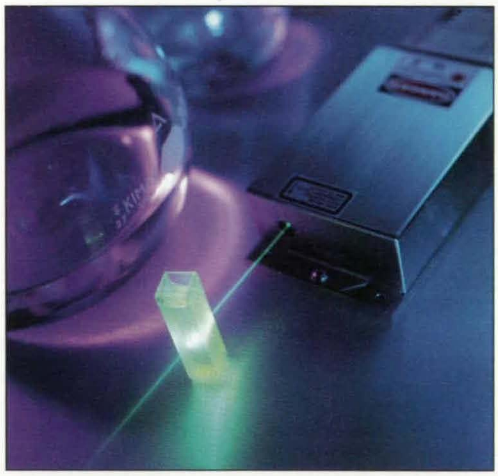

Figure 3. OPSL can extend the limits of laser-induced fluorescence.

serves the bioinstrumentation and inspection fields, while the blue device at 460 nm serves graphic arts and display. The 980-nm product is driven by the growing demands of the telecommunications industry The inherent flexibility of the OPSL design will permit additional wavelengths to be developed to meet other evolving market requirements.

The potential wavelength span of OPSLs can initiate developments to ex-

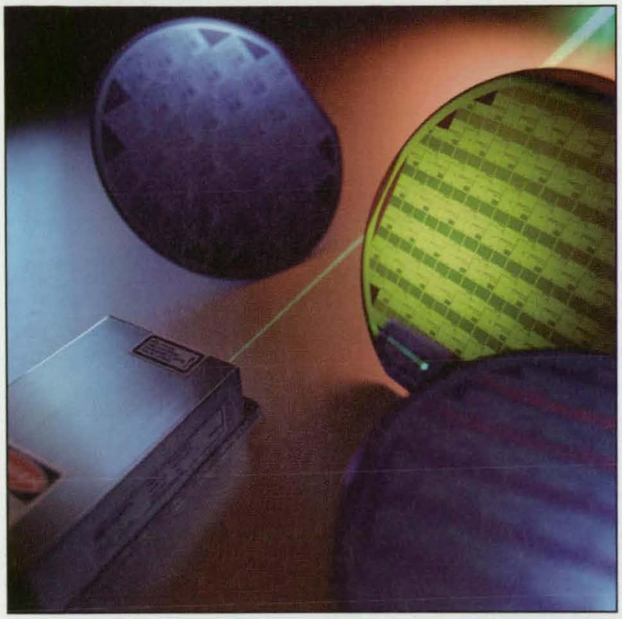

Figure 4. The OPSL's stability and TEM_{00} beam quality promise to increase precision in applications such as silicon wafer and mask inspection.

tend today's laser-induced fluorescence (LIF) dye chemistry for cell sorting, hematology, or DNA sequencing beyond the limits currently set by argon ion and Nd:YAG wavelengths (Figure 3). With the availability of multiple and new wavelengths, OEM designers can increase the diagnostic capability of a single instrument, with which 15 or 20 tests could be run, not just a few.

For the inspection market, OPSL stability and TEM_{00} beam quality promise to increase the precision in applications spanning from silicon wafers to mask inspection (Figure 4). Within these applications, current light-scattering techniques suffer from laser noise masking the return signal from the sample. Since the OPSL is a low-noise laser or "quiet" excitation source, OEMs could design future instruments with a much higher sensitivity. For inspection systems, this can mean the detection of much smaller sample flaws or the detection of even smaller dust particles on surfaces.

The graphic arts fields stand to benefit from the cost efficiency resulting from reliable and efficient OPSL sources with tailored wavelengths and low-amplitude noise properties (Figure 5). For example, in digital photofinishing, where traditional methods employ argon ion lasers at 457 nm, a 460-nm OPSL wavelength matches the absorption of photo emulsions perfectly. OPSL's low-noise performance could also translate into a distortion-free end result, even under close scrutiny by the very sensitive human eye. And in the display market, OPSLs could finally bring the coveted high-power blue component to drive RGB applications.

At near-IR wavelengths, OPSLs offer the highest single-mode fiber-coupled 980-nm output power available, making them ideal for pumping erbium-doped fiber amplifiers. As the demand for dense wavelength division multiplexed systems and other high-performance fiber optic communications uses grows, OPSLs will keep pace with higher pump power.

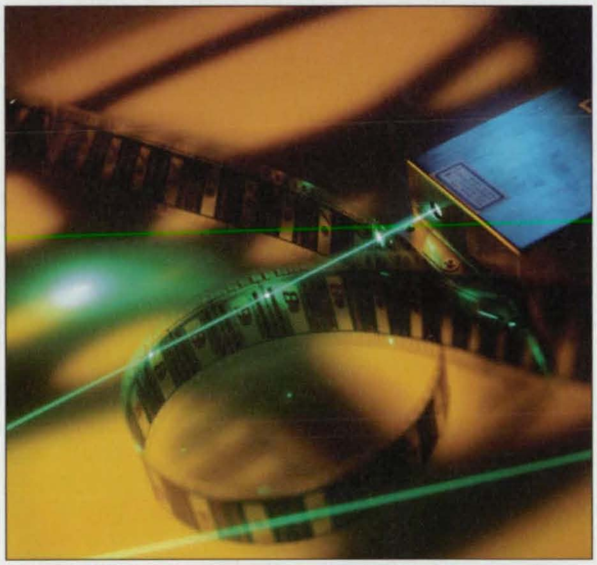

Figure 5. OPSL technology may unseat traditional approaches to photofinishing.

Previous iterations of lasers have eventually scaled in wavelength to meet a range of OEM and customer needs. The design flexibility in the new-generation OPSL technology should permit even wider implementation, dictated by the needs of today's and tomorrow's applications.

For further information, please contact the author of this article, Matthias Schulze, product line manager at Coherent Laser Division. He can be reached at +49-451-3000-303, or by e-mail at matthias.schulze@coherent.com.

Technologies of the Month

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A Very Thin Flexible Laminate of Transparent Plastic and Glass

AGFA

A laminate of a thin borosilicate glass layer and a plastic support layer is provided. The advantages of a glass layer, e.g., dimensional stability, high density, hardness, barrier properties against moisture, solvents and oxygen, are combined with the properties of a polymer layer, e.g. flexibility, by laminating a glass layer together with a polymer layer. One of the layers in the laminate can be a functional layer for such things as security cards, photomasks, semiconductor or electroconductive devices with, or functional layers for use in, flat panel displays. Another application for the laminate is as packaging for electronic chips. The laminate combines all the advantages of a glass material (strong, undeformable, impermeable) with the advantages of a polymer (flexible, lightweight), while both materials are transparent.

For more information go to:
www.nasatech.com/techsearch/tow/agfa2.html
email: nasatech@yet2.com;
phone: 617-557-3837

Glass Substrate for a Thin Film Solar Cell Having a Curved Surface

This technology provides a glass substrate having a transparent electroconductive film suitable for a solar cell having a curved surface shape, which is superior in weather-resistance and crack-resistance to a solar cell using a plastic film as a substrate, and it is thereby possible to produce solar cells of various curved surface shapes. According to the method for producing a glass substrate of this technology, a curve-shape glass substrate having a transparent electroconductive film with good quality can be produced at a low cost by forming the transparent electroconductive film on a glass sheet and then subjecting the resultant glass substrate to a bending treatment without substantially deteriorating the transparent electroconductive film. The solar cell for a sunroof of this technology has the advantages of good aerodynamics, an automobile body efficiently utilizing light incident on the sunroof, and also having a good design.

For more information go to:
www.nasatech.com/techsearch/tow/substrate.html
email: nasatech@yet2.com;
phone: 617-557-3837

New Device Corrects Myopia

Pneumatic keratology is a new procedure that corrects refractive errors, most notably myopia or nearsightedness, without the risks, complications, and expense of laser keratectomy, laser *in situ* keratomiulesis (LASIK), or other invasive surgical procedures. Pneumatic keratology uses a simple device, the EyeModel, which corrects by means of a vacuum. The method and device is a patented invention capable of modeling the shape of the cornea of the eye. The basis of pneumatic keratology is described in a U.S. patent, "Method of Altering the Shape of the Cornea." Pneumatic keratology provides a revolutionary means to correct all refractive errors, such as myopia, hyperopia, and astigmatism with unprecedented simplicity. Unlike other methods, the cornea is not cut, burnt, ablated, or damaged. No tissue is removed and nothing is implanted. The EyeModel has elongated openings that are connected to a vacuum pump with a thin tube. By placing the device on the surface of the cornea and then applying a vacuum, a plastic deformation of the area of the cornea below the openings is achieved. The resulting effect is that the curvature and the refractive power of the cornea and the eye are changed.

For more information go to
www.nasatech.com/techsearch/tow/myopia.html
email: nasatech@yet2.com;
phone 617-557-3837

Light Recycling and Color Scrolling for Brighter Displays

Two efficiency-enhancing techniques would be combined.

NASA's Jet Propulsion Laboratory, Pasadena, California

The efficiencies and thus the brightnesses of flat-panel projectors based on liquid-crystal devices (LCDs) and digital mirror devices (DMDs) would be increased by the combination of a color-scrolling technique and a light-recycling technique, according to a proposal. These techniques were originally proposed separately for the purpose of increasing the efficiencies of LCD-based display devices.

The scrolling-color technique was reported previously in "Using Surface-Plasmon Filters To Generate Scrolling Colors" (NPO-20110), *NASA Tech Briefs*, Vol. 23, No. 2 (February 1999), page 14a. To recapitulate: by use of prisms and surface-plasmon tunable filters, white light from a lamp or other illumination source would be converted into a pattern of scrolling primary colors. The advantage of this scheme is that both polarization components and all colors would be utilized, whereas in prior schemes, most of the light power is wasted through color and/or polarization filtering.

The light-recycling technique was reported in "Low-Absorption Color Filters for Flat-Panel Display Devices" (NPO-20435), *NASA Tech Briefs*, Vol. 23, No. 12 (December 1999), page 34. In this technique, one would replace traditional dye filters with surface-plasmon or interference filters, which are more reflective than absorptive. In addition, the filter and illumination optics would be arranged so that much of the light in all colors and both polarizations reflected from the filters would be sent back through the light-source optics to be reused as illumination.

The present proposal calls for, among other things, a white light source equipped with a reflector and a color-recycling and -scrolling panel (CRSP), as shown schematically in the upper part of Figure 1. The CRSP would contain an array of voltage-tunable or voltage-switchable filters, each of which would transmit one primary color [red (R), green (G), or blue (B), depending on the applied voltage] and reflect the other two primary colors. The reflected light would be bounced back and forth between the CRSP and the light-source reflector until light of each color impinged on its proper color filter. Thus, light in the three colors would be redistributed as needed and relatively little would be lost.

At the first phase of a three-phase operating cycle, the color-filter array could be energized to a color pattern as RGB . . . , for example. In the next phase, the color pattern could be changed to BRG . . . . In the third phase, the color pattern could be changed again to GBR . . . . The net result is that recycling and scrolling of colors would occur in combination. The number of color filters need not match the number of pixels in the display panel to be illuminated panel pixels; the only requirement on the number of filters is that it be an integer multiple 3.

The voltage-tunable or voltage-switchable color filters could be surface-plasmon tunable filters [see "Voltage-Tunable Surface-Plasmon Band-Pass Optical Filters" (NPO-19988), *NASA Tech Briefs*, Vol. 22, No. 8 (August 1998), page 18a]. Alternatively, they could be assemblies of interference or thin-metal film filters, high-index-of-refraction prisms, and total-internal-reflection switches [see "Digitally Tunable Color Filters and Beam Scanners" (NPO-20240), *NASA Tech Briefs*, Vol. 23, No. 9 (September 1999), page 65] that would include layers of an electro-optical material between prisms, as shown in the lower part of Figure 1. In the absence of applied voltage, the electro-optical layer in each switch would have a low index of refraction, so

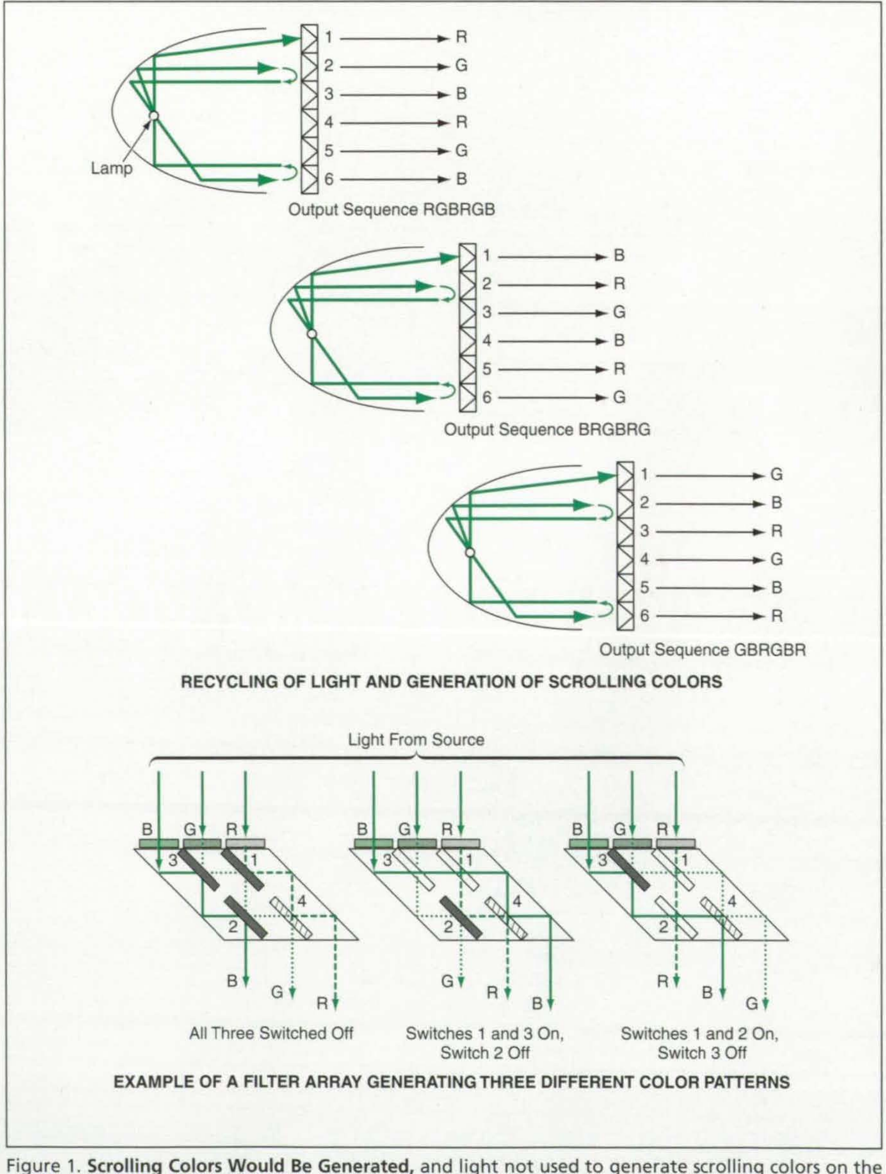

Figure 1. **Scrolling Colors Would Be Generated,** and light not used to generate scrolling colors on the first pass would be recycled and so used on subsequent passes.

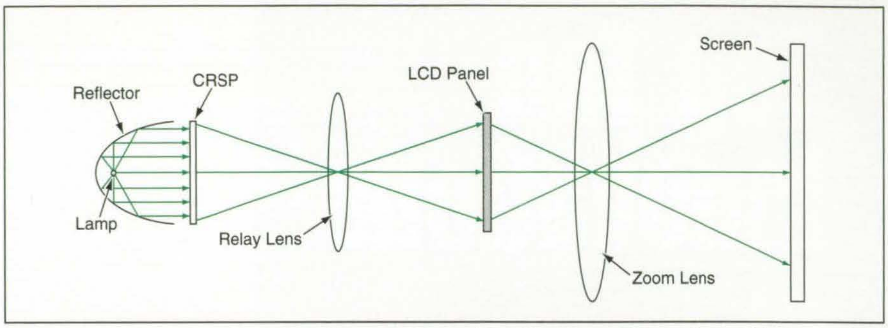

Figure 2. **A Flat-Panel Projector** based on an LCD would utilize the scrolling-color and light-recycling techniques for maximum light-utilization efficiency.

that total internal reflection would occur at the prism/switch interfaces. The application of a sufficient voltage to the switch would increase the index of refraction of the electro-optical layer sufficiently to allow light to pass through. By appropriate switching in this manner, one can cause light of the various colors to travel along various paths in the prisms to obtain various output color patterns.

Figure 2 presents an example of an LCD-based display system that would include a CRSP. The image of the CRSP would be projected into a monocolor LCD panel by a relay lens. A zoom lens would project an image of the LCD onto a screen. It would be necessary to use an electronic driver that would synchronize the scrolling of colors and the modulation of light by the LCD. Similar geometry can be applied to DMDs.

This work was done by Yu Wang of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-21052, volume and number of this NASA Tech Briefs *issue, and the page number.*

Software Automates Processing of SAR Image Data

NASA's Jet Propulsion Laboratory, Pasadena, California

The Automated SAR Image Processor (ASIP) computer program increases the efficiency of production of scientifically useful imagery from raw synthetic-aperture-radar (SAR) image data. In the absence of ASIP, the processing of SAR data is a labor-intensive task, often involving supporting personnel, that requires expertise in the use of a variety of image-data-processing programs, as well as expertise in the scientific specialty of the end user. ASIP captures the diverse components of expertise to assist the scientific end user in obtaining the scientific end product without supporting personnel. ASIP applies artificial-intelligence planning techniques to reason about the interactions and interfaces among the many specialized programs needed to process SAR data. The planning component of ASIP then manages the flow of information and control in order to produce the desired scientific data product efficiently. In one application, for example, ASIP made it possible to produce special maps pertaining to the study of surface winds with only 1/10 the number of manual inputs and 30 percent less central-processing-unit time than would otherwise be necessary.

This program was written by Steve Chien, Forest Fisher, Ronald Greeley, and Edisanter Lo of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20509.

Liquid-Crystal Phase-Shifting Shearing Interferometer

There is no need for critical alignment or focus adjustment.

John H. Glenn Research Center, Cleveland, Ohio

The liquid-crystal phase-shifting shearing interferometer is a common-path interferometer based partly on a lateral-shear-plate interferometer. It bears a partial similarity to the liquid-crystal point-diffraction interferometer (LCPDI), which is also of the common-path type. The phase-shifting nature of this interferometer is expected to increase (relative to prior shearing interferometers) resolution by up to two orders of magnitude. The liquid-crystal phase-shifting shearing interferometer is expected to be useful for measuring spatially varying optical density in a laboratory or manufacturing setting; examples of such densities include the index of refraction of a liquid in a production process, the density and/or temperature of a gas in a combustion system, and the temperature of a fluid in a boiler.

The proper functioning of the LCPDI depends on focusing a laser beam onto a transparent microsphere and, hence, depends on the critical adjustment of a focusing lens by a highly trained technician. Unlike the LCPDI and many other interferometers, the liquid-crystal phase-shifting shearing interferometer can be aligned easily, with no need for critical adjustments by a highly trained technician. Moreover, elimination of the need for focusing on a microsphere also eliminates phase noise associated with inhomogeneities in a focusing lens.

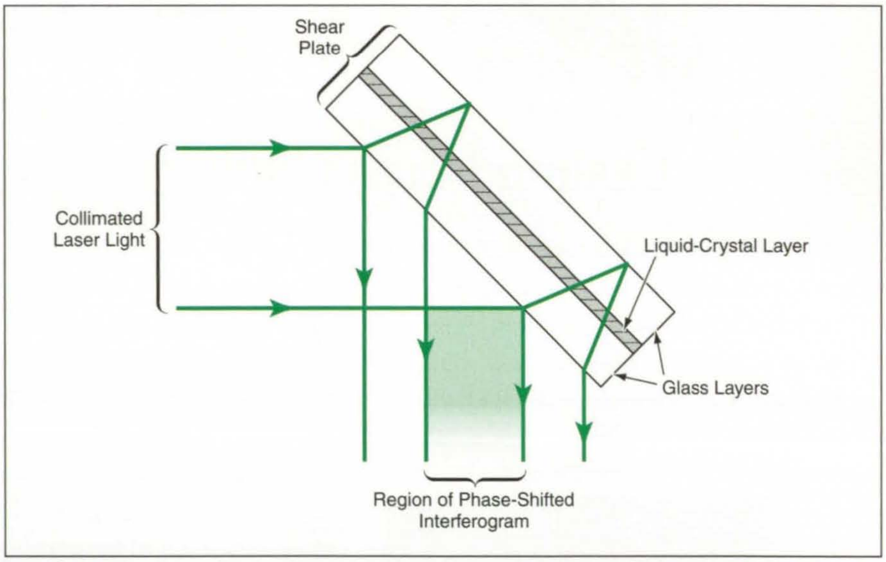
In the liquid-crystal phase-shifting shearing interferometer, collimated light from a laser is incident on a shear plate oriented at an angle of 45° (see figure). Unlike a traditional shear plate, this shear plate contains a liquid-crystal layer that can be used to vary the phase of the light reflected from its rear surface. The amount of shear depends on the effective optical thickness of the shear plate, which is comparable to the combined optical thicknesses of its glass layers. When a voltage is applied across the liquid-crystal layer, the index of refraction of the layer changes, causing the phase of the portion of the incident light reflected from the rear surface to be stepped relative to the phase of this portion when the voltage is not present. Calibration of the phase shift as a function of voltage can produce the phase steps required to implement common phases-stepping algorithms.

The amount of shear varies roughly inversely with index of refraction and thus with the phase. However, calculations for the case of a total shift of one wavelength have shown that the total shift in beam position can be safely neglected because it is more than an order of magnitude below the size of a typical pixel in a charge-coupled-device camera that would be used in implementing a practical version of this interferometer.

In a prototype of this liquid-crystal phase-shifting shearing interferometer, the shear plate is a commercial liquid-crystal phase retarder originally intended for use as an extended-range, variable-retardance wave plate rather than an interferometer component. The manufacturer's specification for reflectance at each surface is less than half of one percent. The device would perform optimally if its front surface were coated with a partially reflective film and its rear surface with a totally reflecting film.

This work was done by DeVon W. Griffin of **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17165.



The Liquid-Crystal Layer in the Shear Plate is used to vary the phase of the light reflected from its rear surface.

Multi-Screen-Image- and Catalog-Viewing Program

NASA's Jet Propulsion Laboratory, Pasadena, California

A computer program enables the single- or multi-screen display of multispectral, multiresolution images — especially astronomical ones — stored as sets of data that range upward in size from hundreds of gigabytes. In cases of multi-screen displays, the software synchronizes the screens so that they act as a single ultrahigh-resolution display. It is possible to pan and zoom smoothly to any part of the data at any resolution. The software can automatically generate composites of multiple sets of data, making it possible, for example, to overlay high-resolution insets on background images or to display a separate source image for each video channel (red, green, or blue). The software includes special features to aid

viewing of astronomical data: these include a capability for displaying catalogs as ASCII text or as image overlays, and a catalog-to-image relational capability that enables the user do such things as select a region of the image and view those objects in the region that are highlighted in both the image and in the catalog. Alternatively, when an object in the catalog is selected, the user can see that object highlighted in the image or can jump to the position of the object in the image.

This program was written by Joseph Jacob of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-30133.

Phase-Retrieval Camera for Optical Testing

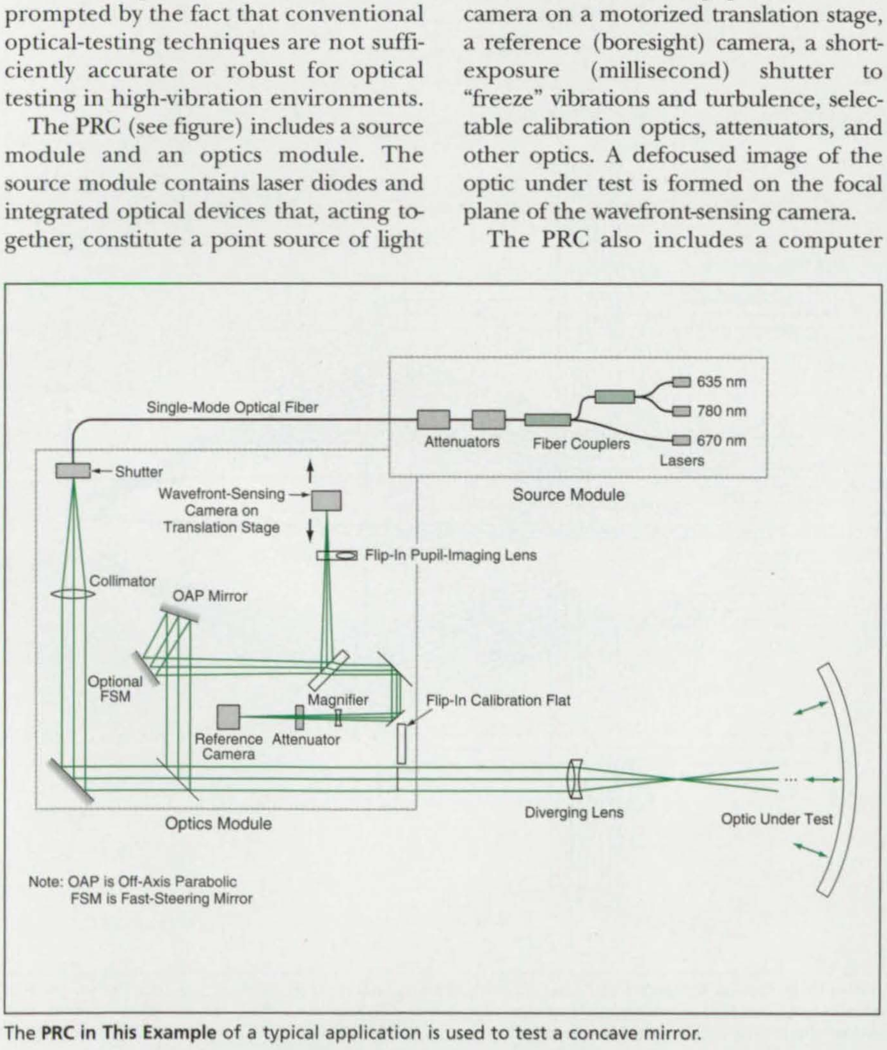
Effects of vibrations and turbulence are removed with the help of a fast shutter.

NASA's Jet Propulsion Laboratory, Pasadena, California

A portable instrument denoted a phase-retrieval camera (PRC) is designed to enable the testing of large, lightweight optics in the presence of vibrations and atmospheric turbulence. The development of the PRC was prompted by the fact that conventional optical-testing techniques are not sufficiently accurate or robust for optical testing in high-vibration environments.

The PRC (see figure) includes a source module and an optics module. The source module contains laser diodes and integrated optical devices that, acting together, constitute a point source of light of three wavelengths. The use of the three wavelengths makes it possible to measure the relative axial displacement (called "piston" in the art) of a segment of an optic under test. The optics module contains a wavefront-sensing (phase-retrieval) camera on a motorized translation stage, a reference (boresight) camera, a short-exposure (millisecond) shutter to "freeze" vibrations and turbulence, selectable calibration optics, attenuators, and other optics. A defocused image of the optic under test is formed on the focal plane of the wavefront-sensing camera.

The PRC also includes a computer



The **PRC in This Example** of a typical application is used to test a concave mirror.

programmed with software that provides a graphical user interface, displays data, controls the operation of the instrument, enables data communication and remote control via the Internet, and performs phase-retrieval, phase-unwrapping, and calibration computations. The phase-retrieval algorithm processes multiple short-exposure images from the wavefront-sensing camera and aligns them with each other by use of boresight calibration images acquired simultaneously by the reference camera. The algorithm generates data and imagery that characterize the wavefront generated by (and thus the surface figure of) the optic under test.

This work was done by David Redding, Andrew Lowman, David Cohen, Fang Shi, and Scott Basinger of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*
NPO-21217

Testing Grazing-Incidence Mirrors at Nearly Normal Incidence

This system enables adequate testing in visible light, without need for a vacuum system.

Goddard Space Flight Center, Greenbelt, Maryland

An optical system that utilizes visible light at nearly perpendicular incidence has been invented for use in testing the surface figures of nominally axisymmetric (paraboloidal, ellipsoidal, or conical) mirrors designed to function at grazing incidence. Such mirrors can be used as the focusing optical elements of x-ray telescopes and x-ray cameras. As explained below, the present system offers advantages over prior systems used to test such mirrors.

It is possible to test a grazing-incidence x-ray mirror by use of visible light at grazing incidence, but diffraction at visible wavelengths limits the achievable angular resolution to the order of one arc minute, whereas a resolution of 15 arc seconds or finer is typically needed for proper diagnosis of the surface figure. It is possible to test such a mirror at finer resolution by use of x rays at grazing incidence in the intended operational configuration, but testing in this way is of limited diagnostic value. Moreover, to prevent excessive absorption of x rays, x-ray testing must be performed in a vacuum chamber: this makes it difficult and time-consuming to manipulate the mirror and test equipment, thereby making testing expensive. The present system utilizes nearly perpendicular incidence to overcome the deleterious effect of diffraction, making it possible to obtain angular resolution of a few arc seconds with visible light and, hence, without need for a vacuum system.

The system (see Figure 1) includes the following components:

- A source of a parallel visible light beam of sufficient diameter,
- The nominally axisymmetric mirror under test,
- A prism that has (1) reflective conical faces with angles and diameter suitably matched to the mirror under test and (2) an axis of symmetry nominally parallel to the light beam,
- A focusing lens, and
- A screen or a charge-coupled-device video camera, located at the nominal focal plane, that captures the image formed by the prism, the mirror under test, and the focusing lens.

The image on the focal plane consists of three components: Component 1 is nominally a point image formed by focusing of that part of the incident parallel light beam that passes directly through the lens. Component 2 is nominally a circular image formed by reflection of the incident light beam from the first conical surface of the prism, fol-

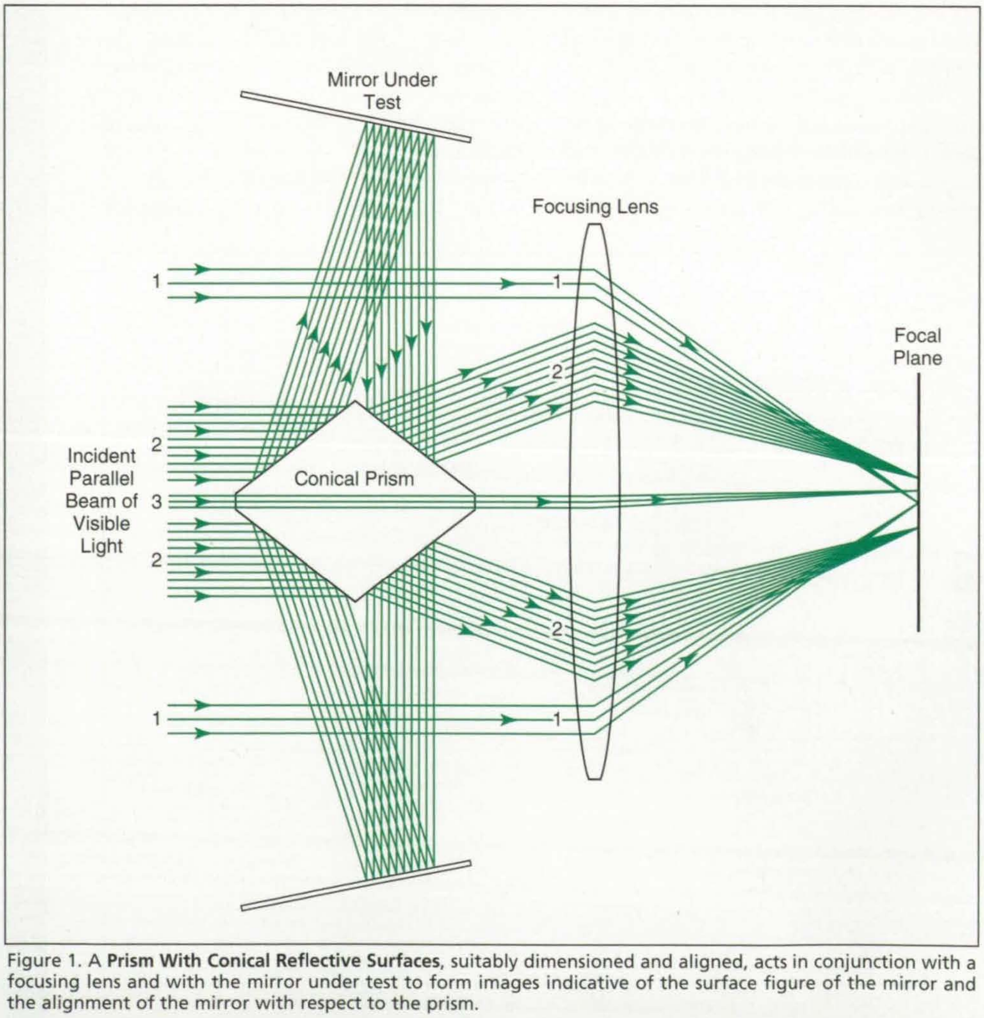


Figure 1. A **Prism With Conical Reflective Surfaces**, suitably dimensioned and aligned, acts in conjunction with a focusing lens and with the mirror under test to form images indicative of the surface figure of the mirror and the alignment of the mirror with respect to the prism.

lowed by reflection from the mirror under test, followed by reflection from the second conical surface of the prism, followed by focusing via the lens.

Component 3 nominally consists of one or more point image(s) formed by passage of part of the incident parallel beam through the central part of the prism and then through the lens. The precise nature of component 3 depends on the specific design of the entrance and exit faces of the central part of the prism: If, for example, the prism is made of optical glass with flat entrance and exit surfaces, then depending on the precision of parallelarity between these surfaces, the resulting single point image may or may not coincide with the point image of beam 1. If, for another example, the prism is made of a metal, then the central core of the prism can be drilled out and a glass refractor with, say, three facets can be inserted to refract the incident parallel beam into three detected beams that, in turn, are focused to three point images on the screen (see Figure 2). These point images, in conjunction with the component-1 point image, can be used as fiducial marks for monitoring the orientation of the prism with respect to the incident parallel beam.

Among the most important features of this system are that the parallel light beam is the sole reference for the entire setup and the system inherently provides fiducial marks for its own alignment: The parallel light beam defines the direction of the optical axis. Once the axis of symmetry of the conical prism has been made parallel to the incident light beam and its position fixed, then the optical axis of the entire setup is fixed. The positions of the three component-3 point images with respect to the single component-1 point image serve as real-time indications of the alignment of the axis of symmetry of the prism.

When the optical axes of the conical prism and the mirror under test and the conical prism are perfectly aligned with each other, and provided that the mirror under test is perfect, then the image on the focal plane is as shown in the upper part of Figure 2. If these two optical axes do not coincide and/or if the mirror under test is not perfect, then the image becomes distorted, as shown by example in the lower part of Figure 2.

This work was done by William W. Zhang of **Goddard Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*
GSC-14365

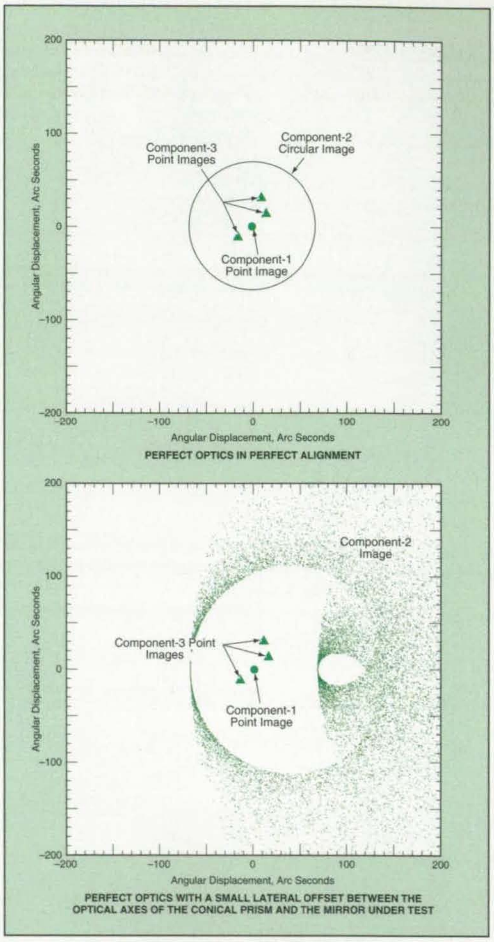


Figure 2. **These Images Are Typical** of a system like that of Figure 1 in which perfect optics are tested in perfect and imperfect alignment, respectively.

Making Digital Composite Images for Technical Illustration

Drawings of facilities to be modified can be made in less time.

John F. Kennedy Space Center, Florida

A method of generating three-dimensional composite digital images can serve multiple purposes in technical illustration. The method was devised to accelerate and facilitate the design of new electric lights and receptacles for large buildings, and can just as well be applied to the design, redesign, and analysis of other buildings and equipment.

In the original application that motivated the development of this method, it would have taken an excessively long time to make traditional-style drawings by the traditional method, because of the complexity of the facilities. Accordingly, a major element of the method is that one makes detailed three-dimensional drawings of only those parts of the facilities and equipment that are to be modified. Data on the parts not to be modified are acquired by photographing the facilities in their present state by use of a digital camera and, if necessary, retouching the digital photographs by use of commercial software developed for that purpose.

Computer-aided-design (CAD) software is used to generate three-dimensional computational models from the new drawing data. Materials are assigned to the surfaces of the models. The models are rotated to match the perspective and lighting of the digital photographs, and are then composed onto the photographs. If necessary, hidden-line isometric profiles are created from the three-dimensional models and rendered as details in drawings. The models are created only once and are reused in different views; they can also be reused on different projects.

This method greatly reduces the amount of time needed to make drawings for modifications of facilities. In this method, unlike in the traditional method, little or no time is spent in research of prior drawings or in measuring dimensions. The composite images generated by this method have higher levels of detail and are easier to understand, relative to traditional drawings. An additional and unobvious advantage afforded by these images is that they can reveal conflicts in original designs of facilities and equipment. The composite images can be printed in color, generated as dozens of different file formats [including portable document format (.pdf)] that can be transmitted by electronic mail, incorporated into CAD drawings, or documents generated by word-processing software, and/or attached to MAXIMO work orders.

This work was done by Arlene S. Reese, Thomas Bigelow, and Robert C. Kemmerling of United Space Alliance for **Kennedy Space Center**.
KSC-12288

Fiber-Optic Phase-Locked Loop Sensitive to Local Strain Only

Optical fibers are made insensitive to strain except over a short sensory length.

Langley Research Center, Hampton, Virginia

The figure schematically depicts an apparatus for measuring strain at only one designated location on a structure. The apparatus is a fiber-optic phase-locked loop, wherein strain in a multimode optical fiber gives rise to a change in the phase of modulation of a laser beam that propagates along the fiber. The optical phase-locked loop makes it possible to perform sensing by use of a multimode optical fiber (in contradistinction to a single- or few-mode fiber as in some other fiber-optic sensor systems). Unlike in other fiber-optic-based sensor systems, the phase change in this system does not occur in response to strain integrated along the entire fiber-optic path. Instead, this system includes lead-in and lead-out strain-insensitive lengths of optical fiber connected to a short strain-sensitive length of optical fiber that is affixed to the structure at the desired measurement location. Strain in the short sensory length produces a phase change, but strain in the lead-in and lead-out portions does not.

The output of a voltage-controlled oscillator (VCO) is used to modulate the laser light and to supply a reference signal to a double balanced mixer. After traveling along the strain-insensitive and strain-sensitive lengths of optical fiber, the modulated laser signal impinges on a photodetector, the output of which is amplified and mixed with the reference signal. A filter removes the radio-frequency component of the mixer output, passing only the DC or low-frequency component, which component constitutes a DC error voltage. The phases of the fiber-optic-propagated and reference signals are maintained at quadrature by feedback of the DC error voltage to the VCO. A change (caused by strain) in the phase of the modulation manifests itself as an error voltage and, by virtue of the feedback, is compensated by a change in the modulation frequency. The frequency is monitored by a counter.

A multimode optical fiber can be made more or less sensitive to strain through selection of the fiber core and cladding materials. Assuming that the fiber can be approximated as weakly guiding (meaning, essentially, that the index of refraction of the core exceeds that of the cladding by an amount <<1), it can be shown that the condition for complete insensitivity to strain (zero phase shift in response to strain) is given by

$$n_{core} = (2/P_{eff})^{1/2},$$

where n_{core} is the index of refraction,

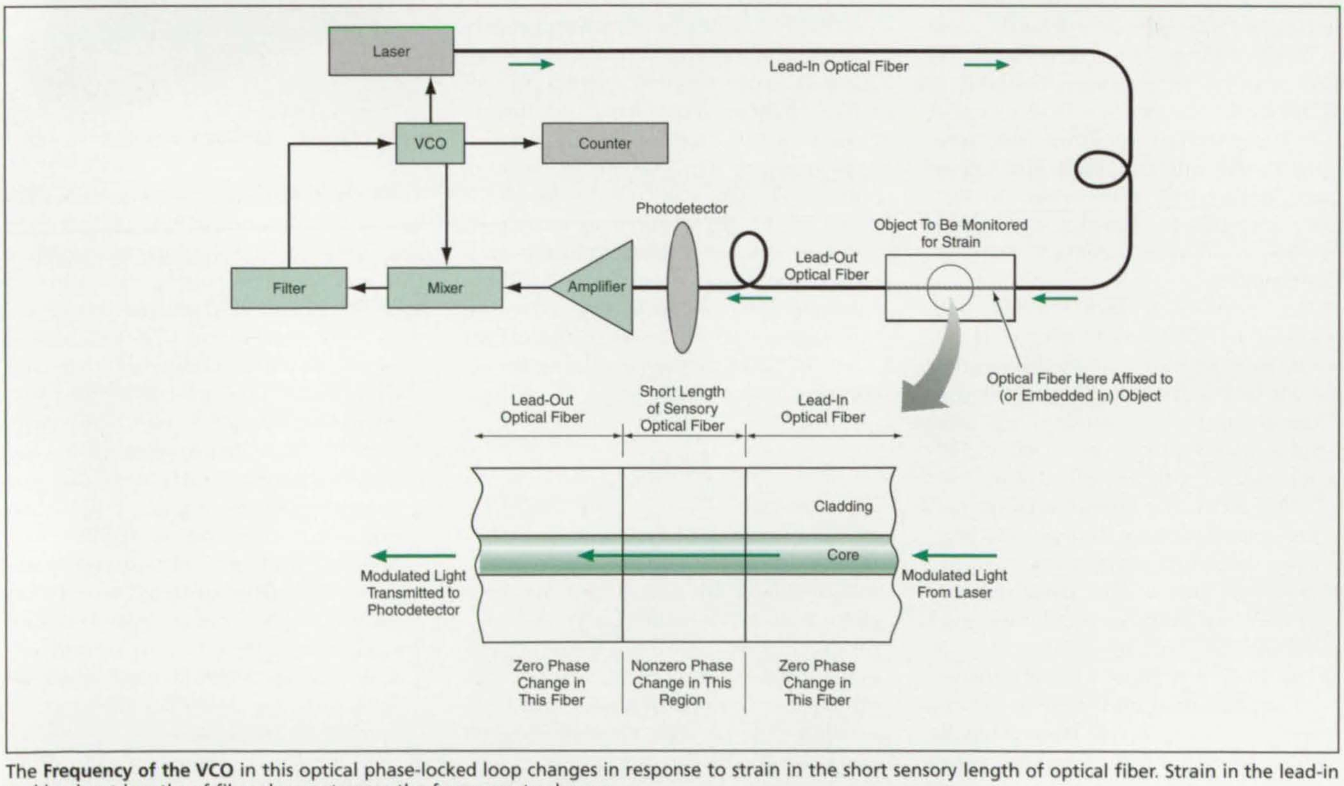
$$P_{eff} = [P_{12} - \nu_f(P_{11} - P_{12})]/2,$$

ν_f is the Poisson's ratio of the fiber, and P_{11} and P_{12} are the strain-optic coefficients of the fiber.

The insertion of appropriate parameters in these equations leads to the conclusion that a strain-insensitive optical fiber is one in which the core has a very high index of refraction (4.5 is an approximate representative value). Germanium is one example of a material suitable for a multimode optical fiber with a very high index of refraction.

This work was done by Claudio O. Egalon and Robert S. Rogowski of **Langley Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*

This invention has been patented by NASA (U.S. Patent No. 5,780,844). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Rheal Turcotte, Technology Commercialization Program Office, NASA Langley Research Center at (757) 864-8881 or e-mail at r.p.turcotte@larc.nasa.gov. Refer to LAR-15159.



The **Frequency of the VCO** in this optical phase-locked loop changes in response to strain in the short sensory length of optical fiber. Strain in the lead-in and lead-out lengths of fiber does not cause the frequency to change.

PRODUCT GUIDE: OPTICAL TIME DOMAIN REFLECTOMETERS

With the Internet, Ethernet, and metropolitan area networks (MANs) again beginning to put pressure on the installed capacity of fiber optics, the importance of test instrumentation cannot be overstated. That's where the optical time domain reflectometer (OTDR) comes in. It is the premier instrument in testing a fiber optic link, for several reasons, first and foremost its ability to perform and store multiple tests. Such measurements as splice and connector location, fiber attenuation across the link, reflectance, and fiber length and break location can all be determined with an OTDR. If the user is interested in attenuation of the signal through the fiber's length, he can obtain only the total of the loss with an optical power meter. But the OTDR will give him an event map on a monitor, showing the attenuation across the whole fiber span, as well as indicating signal level versus distance, the location of any fusion splices or bend loss and of any breaks in the fiber.

Another factor that sets the OTDR apart is that, because its principle is like that of a radar and the transmitter and receiver are on the same instrument, the user needs access to just one end of a fiber to test a link. Most manufacturers, however, recommend that the testing be done from both ends if both are available. Exfo, for one, notes that bidirectional OTDR averaging is essential for users who must do extensive fiber link commissioning and documentation, as well as for those who are sensitive to their cable plant loss budgets.

The basic components of an OTDR include a light source, pulse generator, coupler, detector, A/D converter, and controller, in addition to software. The source emits pulses of light that are directed through the coupler into the fiber under test. The pulses are averaged and the fiber characterized. Most manufacturers offer one or more "mini-OTDRs," handheld or relatively compact instruments that can be taken into the field.

AGILENT TECHNOLOGIES

www.agilent.com

Agilent's flagship OTDR is the series E6000-B mini-OTDRs for single-mode networks. Two in the series are designed for 1310-nm single-mode fiber, and three others for 1310 and 1550 nm. Dynamic range varies, from 28 dB to 45 dB (1310).A fiber break locator looks exclusively for breaks, which are displayed quickly. The E6000B combines 16,000 data points with a minimum sample spacing of 8 cm. The E6010B is aimed at testing at 1625 nm, with a dynamic range of 40 dB, and can be used to test the optical supervisory channel capability of WDM links. A series of modules enables the basic design to cover the wavelengths 850 nm and 1300 nm. Out-of-band testing also allows users to do a fiber test while transmitting data at 1310 or 1550 nm. The series comes in 10 standard models.

❖The series of rack OTDRs—the E6053A, E6058A, and E6060A— based on the design of the E6000B—can be built into a system and controlled remotely by a PC. Dynamic range varies from 34 dB (1550) to 40 dB (1310). When used with an optical switch and a PC, these instruments can be used for commissioning and monitoring a fiber optic link automatically. With a keyboard and a VGA monitor, these devices can serve as standalone mini-OTDRs.

❖The 8147 is designed for installation, commissioning and bench applications. Its "Easy Mode" feature lets the user preprogram complete procedures, so that with just a few keystrokes, he gets standardized measurements. Extended in-depth analysis, including two-way measurements, delta measurements, and comparison of up to four traces, is available on-line. A return loss graph permits the user to see the reflectance of individual events at a glance, as well as the total return loss of the link. The 8147 series comes in 11 standard versions, with dynamic ranges spanning from 30 dB (1310) to 45 dB (1550).

❖The E6091A OTDR Toolkit II is described by Agilent as ideal for post-processing, analyzing, and batch processing Bellcore GR-196 bas0ed OTDR files. Systems employing the E6091 software can transfer data serially to a PC running Windows 95, 98, or Windows NT. The data can be saved for use in a spreadsheet or database. Other features include comparison of up to four traces simultaneously; Trace Manager, to enable high-speed multiple trace transfer between the OTDR and PC; and two-way averaging for accurate loss calculations.

EXFO

www.exfo.com

Exfo says that its FTB-7000B series has more than 20 models, with instruments suitable for the shorter distances of local area networks (LAN) and metropolitan area networks (MAN) as well as the greater distances in long-haul networks. The company claims links exceeding 200 km can be characterized using the 45-dB dynamic range model. Single-mode modules are available at 1310 nm, 1410 nm, 1550 nm, and 1625 nm, and multimode at 850 nm and 1300 nm. A Visual Fault Locator option gives the user troubleshooting capability in LAN/WAN and metropolitan networks.

EXFO's FTB-400 Universal Test System

❖Exfo recommends its FTB-9000 optical switch module combined with the FTB-7000 OTDR for batch fiber testing in patch panels or bare ribbon testing during installation. Dynamic ranges go from 31 dB to 42 dB. The company offers complete OTDR testing kits, including multifiber, ribbonized, and bare ribbon configurations. For unconventional wavelength windows, the company's 1625-nm module can characterize L-band systems, and the 1400-nm module can be used with the new fiber that has no water-peak attenuation.

❖The ToolBox software in the FTB-7000B module has two modes: auto

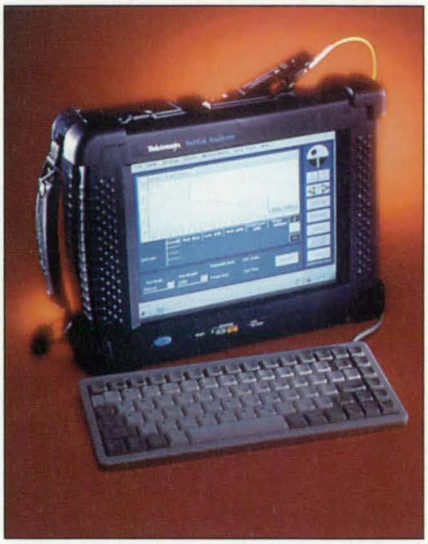
mode and advanced mode. The first has preset test parameters and a choice of single- or dual-wavelength OTDR testing. The second allows the user to manually set all acquisition parameters, including index of refraction and helix factor.

- ❖The FTB-100B mini-OTDR has an internal memory of 70 traces, and additional storage capacity of up to 6000 traces. The module is available at four wavelengths: 1310 nm, 1410 nm, 1550 nm, and 1625 nm. Dynamic ranges to up to 45 dB. It contains an InGaAs detector power meter that can measure in dB, dBm, and watts. The trace has 52,000 data points, and a sampling resolution down to 8 cm.
- ❖Exfo's FTB-400 Universal Test System comes in two configurations: a two-slot OTDR and loss testing combination that has more than 500 OTDR and loss capabilities, and a seven-slot configuration that has more than 1000 testing combinations, including polarization mode dispersion, DWDM modules, ribbon test kits, switches for high-fiber-count testing, and OTDR and loss testing. It has more than 20 OTDR modules, mated to four single-mode and two multimode wavelengths.

TEKTRONIX
www.tektronix.com

Tektronix calls its line of mini-OTDRs its "next-generation entry" into long-haul fiber installations of 300 km and up, but says it also addresses short- and mid-range fiber optic networks. The line, called NetTek™ OTDR, combines OTDRs and optical power meter modules with the NetTek Analyzer, the control and display platform that houses these modules. There are nine OTDR modules, with wavelengths ranging from 850/1300 nm to 1550/1625 nm, and dynamic range from 34 dB to 44 dB.

- ❖Tektronix says that the OTDRs address virtually every prevailing mode, wavelength, and fiber optic network, and both in-band and out-of-band measurements. The NetTek platform simultaneously accepts up to four OTDRs plus an optical power meter. The platform is designed to accommodate an expanding line of measurement modules, including the YBT250, used for Base Station testing, and others currently in development.
- ❖The NetTek platform has standard internal memory of 7 MB available for storage and running WinCe applications. A floppy disk and a 128-MB memory card are optional. A port supports standard PCMCIA memory cards. Display range is 0 to 320 km for single-mode fiber and 0 to 32 for multimode. The OTDRs can operate with pulse widths from 10 nanoseconds to 20 microseconds. Thirty-two thousand measurement points is standard.
- ❖NetTek OTDR modules use Tektronix's IntelliTrace Plus technology, which automatically optimizes test parameters so the user does not have to.



Tektronix's NetTek mini-OTDR

FOTEC
www.fotec.com

Fotec says that its Fiber U OTDR converts any Windows PC into a full-function optical time domain reflectometer. It consists of a mainframe and separate optical plug-in units for measuring characteristics of either single-mode or multimode fiber. Dynamic ranges are 25 dB for the 850/1300-nm multimode devices and 28/27 dB for the 1310/1550-nm single-mode devices and the combination multimode/single-mode device. Fotec says the unit can be ordered in a field kit with carrying case and launch cable. It can read from 2 to 180 kilometers, and display 8 traces simultaneously.

NOYES
www.noyes-fiber.com

Noyes's M600 line of mini-OTDRs has user-installable modules for testing multimode (850/1300 nm) and single-mode (1310/1550 nm) fiber links. For the multimode M600-K-MM1-xx dynamic range is 21/23 dB; for the single-mode M600-K-SM1-yy it is 26 dB; for the multimode/single-mode M600-QUAD-xx-yy it is 21 dB (850 nm), 23 (1300 nm), 26 (1310 nm), and 26 (1550 nm).

- ❖The standard mainframe includes a color LCD display, a floppy disk drive, and nonvolatile memory that can store up to 50 traces. The software supports trace manipulations such as two-way averaging, trace overlay, graphing, and batch printing. Pulsewidth and range can be set automatically or manually for maximum flexibility. The M600 can automatically increment and include a fiber number in each file name to speed up identification.

ANDO
www.ando.com

Ando's AQ7250 mini-OTDR is described by the company as offering a range of functions and capabilities ideal for field use. The single-mode unit's wide dynamic range of 41.5 dB (1310 nm) and 39.5 dB (1550 nm) enables measurement of cables over extra-long distances, the company says, and its high measuring speed means that it can measure a splice loss of 0.5 dB from 70 km away in just 20 seconds. The screen updates a minimum of twice per second in preview mode, allowing real time checking of changes in the state of optical fibers in less than a second. On batteries the AQ7250 has an operational life of about eight hours under normal service conditions, so the user can get a full day's work on one charge.

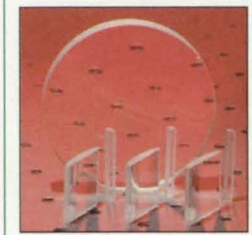
Ando's AQ7250 mini-OTDR

Automatic detection of splice losses, return losses, and other items exceeding preset levels is possible. When calculations are complete, the list screen is displayed, enabling the user to view distances to splice points, splice loss, return loss, and total losses, and other items at a glance.

- ❖Ando also offers the AQ7410 and AQ7410B reflectometers for measuring high-resolution return loss distribution of waveguides and optical modules. Using a wavelength-tunable narrow-band light source unit, it is possible to obtain optical loss distributions of waveguides and optical modules by observing Rayleigh backscattered light.

New Products

PRODUCT OF THE MONTH



Fiber Bragg Grating Write Optics

Alpine Research Optics, Boulder, CO, introduces a series of optical components intended for fiber Bragg grating (FBG) writing applications with excimer, ion, or solid-state lasers. The product line encompasses mirrors, beamsplitters, and spherical and cylindrical lenses. Offered, with the beamsplitters, in 1-in. and 2-in. diameters, the mirrors nominally provide reflectivity of greater than 99.5 percent at 244 nm, 266 nm, or 248 nm and greater than 96 percent at 193 nm, at either 0- or 45-degree angle of incidence. The lenses come in sizes of up to 75 mm with radii of curvature between 0.05 and 10 meters and antireflection coatings for the same wavelengths.

For Free Info Circle No. 730 or Enter No. 730 at www.nasatech.com/rs

Liquid Crystal Polarimeter

Meadowlark Optics, Frederick, CO, offers a compact liquid crystal polarimeter that, with no moving parts, measures the state and degree of polarization on an incident beam. The polarimeter uses Meadowlark's proprietary VersaLight technology. Available in both free-space and optical-fiber versions, it has accuracy to 1 percent, according to the company. The two versions of the polarimeter cover the entire spectrum, from visible to near-IR (400-1100 nm) and into the IR (1100-2200 nm). The accompanying software displays the polarization state as a Stokes parameter, a vector on a Poincaré sphere, and a polarization ellipse.

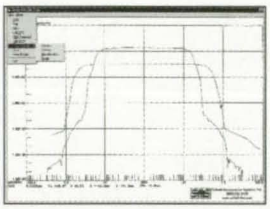
For Free Info Circle No. 731 or Enter No. 731 at www.nasatech.com/rs

Compact Lead Screw Positioners

From Del-Tron Precision, Bethel, CT, come new compact lead screw positioners, which the company calls the smallest-ever member of the company's Posi-Drive line of stages. Their height is 1.250 in. and their width 1.380 in. Del-Tron says the stages provide the same 0.0001-in. straight-line accuracy per inch of travel and 0.0001-in. repeatability as the existing Posi-Drive line. The stages have a 0.125-in. diameter lead screw, an anti-backlash nut, and a flexible zero-backlash coupling that accepts a NEMA 14 motor. They provide a load-bearing capacity of up to 40 lb. Available in travel lengths from 1 in. to 4 in., the positioners can have either linear ball or crossed roller slides.

For Free Info Circle No. 734 or Enter No. 734 at www.nasatech.com/rs

Stray Light Analysis Software



Stellar Optics Research International, Thornhill, Canada, introduces SOLEXIS™ software Version 2.1.2 for stray light analysis in ground- and space-based applications. The software can perform optical design and materials selection in development of systems for which optical, thermal, stray light, and scatter performance is critical, including cameras, scanners, telescopes, and so forth. Scatter data is bidirectional reflectance and transmittance distribution function data (BDRF and BTDF) essential to improve image quality, spot size, contrast, signal-to-noise ratio, ghosting, and sharpness. TracePro® and ASAP™ both accept scatter data from SOLEXIS.

For Free Info Circle No. 738 or Enter No. 738 at www.nasatech.com/rs

Spectroscopic Detectors with High Speed

Roper Scientific, Trenton, NJ, offers its Princeton Instruments family of Spec-10® detectors for spectroscopy in speeds of 2 MHz and 50 kHz in addition to 100 kHz and 1 MHz. The company says that the 50-kHz speed lowers the read noise for several of the models to less than 3 electrons per pixel per second, and is intended for applications such as high-sensitivity Raman and fluorescence spectroscopy. The 2-MHz setting delivers faster spectral acquisition and is useful for pump-probe methods and high-repetition-rate experiments. Spec-10 systems can be configured with a number of exclusive front- and back-illuminated CCDs.

For Free Info Circle No. 739 or Enter No. 739 at www.nasatech.com/rs

Nanoelectronic Devices With Precise Atomic-Scale Structures

Field-effect transistors with nanometer dimensions are under development.

Ames Research Center, Moffett Field, California

Since its invention in 1948, the transistor has revolutionized everyday life. The electronics revolution is based on miniaturization of transistors; smaller transistors are faster, and denser circuitry has more functionality. Transistors in the present generation of integrated-circuit chips have sizes of ≈0.18 μm, and the electronics industry has completed development of 0.13-μm transistors, which will enter production within the next few years. Industry researchers are now working to reduce transistor sizes below 0.1 μm — a thousandth of the width of a human hair. However, studies indicate that the miniaturization of silicon transistors will soon reach its limit.

For further progress in microelectronics, it is necessary to turn to nanotechnology. Rather than continuing to miniaturize transistors to a point where they become unreliable, nanotechnology offers the new approach of building devices on the atomic scale. One vision for the next generation of miniature electronic circuitry is that of atomic-chain electronics; according to this vision, each device is composed of atoms aligned on top of a substrate surface in a regular pattern. The Atomic Chain Electronics Project (ACEP) — part of a nanotechnology group at Ames Research Center — has been developing the theory for understanding atomic-chain devices, and a patent for atomic-chain electronics has been filed and is now pending.

The use of dopants is critical to the functionality of transistors. Dopants are impurities intentionally added to the semiconducting transistor channel to raise or lower the device switch-on voltage. Typically, a macroscopic transistor (one with a size of the order of 10^{-6} m) contains several thousand dopant atoms that, on the scale of the overall device, appear to be smeared out as a dopant "jelly," as illustrated in the top part of Figure 1. Because of the large number of dopant atoms, the precise location of each dopant atom is not very important to the functioning of the transistor. However, when the size of a transistor is reduced to the range of 10^{-8} to 10^{-7} m, as illustrated in the middle part of Figure 1, the number of dopant atoms is less than about 100, in which case the position of each dopant atom does matter. Current manufacturing techniques do not provide the means to control the locations of the few dopant atoms precisely, and as a result, small variations in functioning occur among transistors. Such variations are fatal when millions or billions of transistors are integrated in a computer chip, because the variations can cascade from one device to the next, eventually giving rise to a malfunction. A solution of this aspect of the miniaturization problem, devised by the ACEP, is to create all the device structures with atomic chains laid out in a regular precise pattern by anchoring atoms to a substrate, as illustrated in the bottom part of Figure 1.

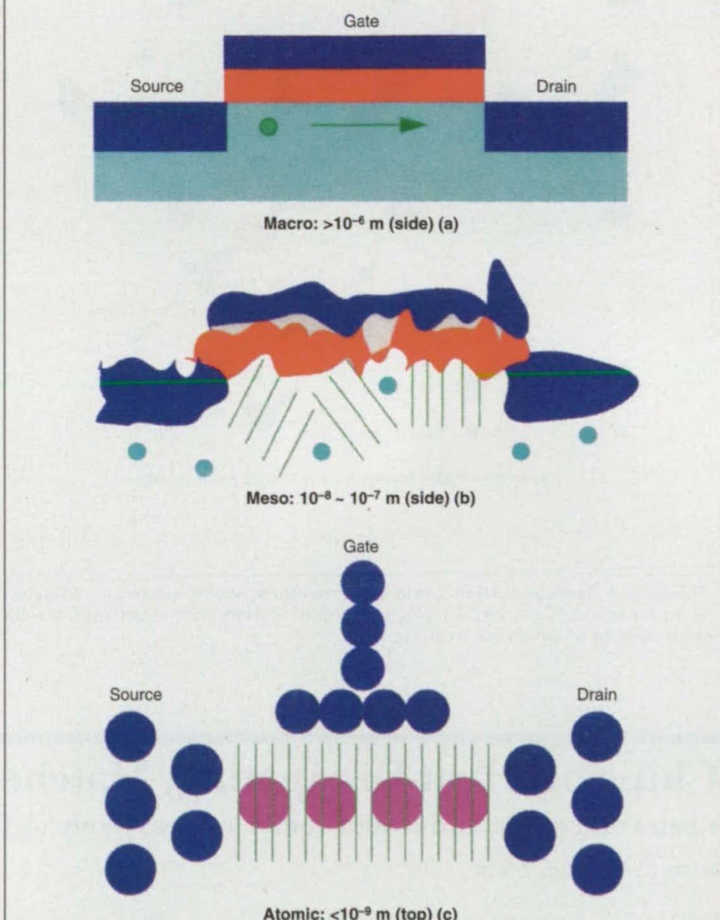


Figure 1. **Transistors Have Been Miniaturized,** starting from the macroscopic scale, where thousands of dopant atoms can be regarded as being in a smooth distribution that determines the switch-on voltage. At the mesoscopic scale, transistors have different switch-on voltages, depending on precisely where the dopant atoms are located. To prevent such unit-to-unit variations, the next step in miniaturization will not be accomplished by making conventional transistors smaller: instead, transistors with dimensions <1 nm will be made from chains of precisely positioned atoms.

A second critical aspect of the functioning of a transistor is gain: the output of the transistor should be a magnified version of its input. ACEP research has led to the conclusion that in designing atomic-chain transistors to produce gain, one should exploit the field effect, which is the only mechanism verified experimentally so far at the atomic scale. Semiconductors conduct current only when a gate voltage is (is not) applied — field effect. Metals always conduct current. A field-effect transistor uses a semiconductor for the channel

and a metal for electrodes, and this is how it achieves large gain. Thus, it is necessary to devise chains with semiconductor and metal properties. First, the ACEP team tackled a simple problem theoretically: If one can arrange silicon atoms along a line floating in air, is this chain semiconducting? The answer is surprising: although bulk or thin-film silicon is semiconducting, an isolated chain of silicon atoms is always metallic. Fortunately, ACEP research also leads to the finding that a magnesium chain is semiconducting, even though bulk magnesium is metallic.

Of course, it is not possible to float atoms in air: it is necessary to place them on top of a substrate. Surface atoms of the substrate attract atoms in the chain and hold them at fixed positions. The surface of a substrate can be made to have atomic-scale corrugations, and these can be used to create a precise pattern for atomic-chain electronics. However, the attractive force between the substrate and chain atoms that are simply placed in the corrugations is too weak to secure atoms reliably. ACEP research has led to the conclusion that a chemical bonding scheme is needed to secure chain atoms reliably, and to the further conclusion that the properties of a chain are strongly influenced by the substrate material and surface orientation when chemical bonding is used. Indeed, the same atomic chain can be either metallic or semiconducting, depending on the number of chemical bonds between a chain atom and the substrate atoms.

A further concern is that electrons traveling along an atomic chain can detour into the substrate through chemical bonds and possibly leave through a neighboring chain, resulting in the short-circuiting of two atomic chains. Such short circuits are fatal for electronic applications and must be avoided. ACEP research has clarified the conditions under which the substrate surface can be made electrically insulating in a chemical-bonding scheme. Among the findings of this research are that silicon and germanium crystals can be good insulating substrates.

Thus far, the ACEP team has made the first step toward the development of atomic-chain electronic devices. On top of a silicon substrate, it is possible to attach germanium atoms with two chemical bonds each, as shown in Figure 2. The resulting structure is a semiconducting chain on an insulating substrate. Nearby chemical bonds on the substrate are saturated with hydrogen atoms, so that they are electronically inactive. Such a chain can be a component of a field-effect transistor on an atomic scale.

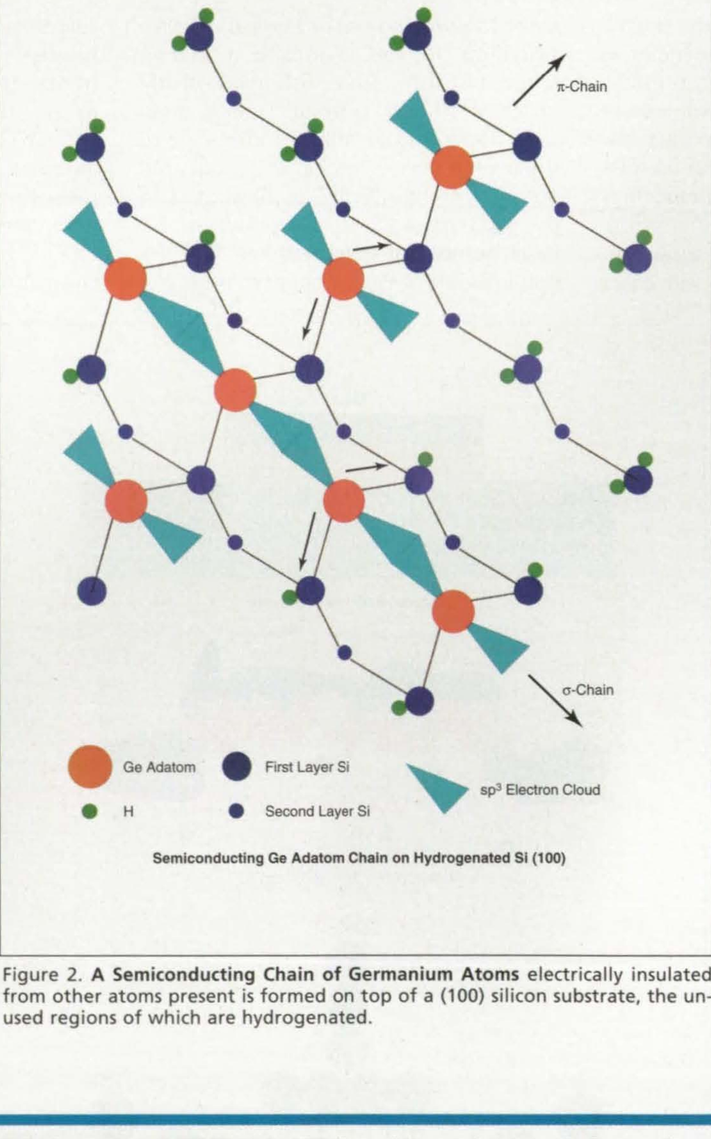


Figure 2. **A Semiconducting Chain of Germanium Atoms** electrically insulated from other atoms present is formed on top of a (100) silicon substrate, the unused regions of which are hydrogenated.

This work was done by Toshishige Yamada of Computer Sciences Corp. for **Ames Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14246.

Mounting Flip Chips on Heat-Dissipating, Matched-CTE Boards

Integrated-circuit chips can run cooler, and solder joints are less likely to fail.

John H. Glenn Research Center, Cleveland, Ohio

"Flip chip on board (FCOB) with high thermal conductivity and tailored coefficient of thermal expansion (CTE)" denotes a developmental concept for relatively inexpensive, lightweight packaging of electronic circuits to accommodate high densities of components and of interconnections. The concept addresses several issues that pertain to flip-chip performance and reliability and to the integration of flip chips with other components: These issues include minimization of undesired mismatches of CTEs between flip chips and printed-wiring boards (PWBs), removal of heat from high-power flip chips, and the need to maximize stiffness while minimizing weight.

Usually, a conventional PWB is made of an epoxy-matrix/glass-fiber laminate, called "FR-4," with copper surface layers that can be etched to form signal and power conductors. A PWB of the present developmental type includes a core layer that contains a carbon cloth, sandwiched between FR-4 outer layers. Typically, the thickness of the carbon-

cloth layer is about one-third the overall thickness of the laminate.

Carbon cloth is used in the core layer because it has several properties that are desirable with respect to the issues mentioned above. These properties include the high thermal conductivity of carbon fibers (up to 1,100 W/m·K), low CTE [$\ll 10^{-6}$ (°C)$^{-1}$ in some cases], low mass density [≈0.07 lb/in.^{3} (1.9 kg/m^3) for carbon versus ≈0.1 lb/in.^{3} (2.8 kg/m^3) for aluminum], and high stiffness [up to ≈42 Mpsi (≈290 GPa) for carbon versus ≈10 Mpsi (≈69 GPa) for aluminum].

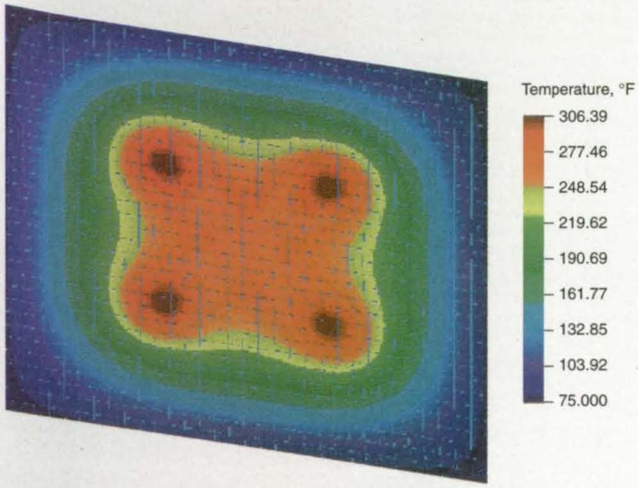
The use of a carbon-fiber core layer to increase the thermal conductance of a PWB and thus the ability of the PWB to dissipate heat offers two benefits. One benefit is higher reliability: It has been estimated that in many cases, lowering the temperature of operation of electronic components by 10 °C approximately doubles the mean time between failures of the components. The other benefit is that lower operating temperatures enable components (especially data processors) to function at greater speeds and efficiencies.

Thus far, thermal testing of specimens and finite-element modeling of carbon-fiber-core FCOBs have shown the potential for matching of CTEs and lowering operating temperatures of components. In one example in the temperature analysis (see figure), the peak temperature under a flip chip was estimated to be ≈277 °F (≈136 °C) on a conventional FR-4 PWB but only ≈129 °F (≈54 °C) on a carbon-fiber-core PWB.

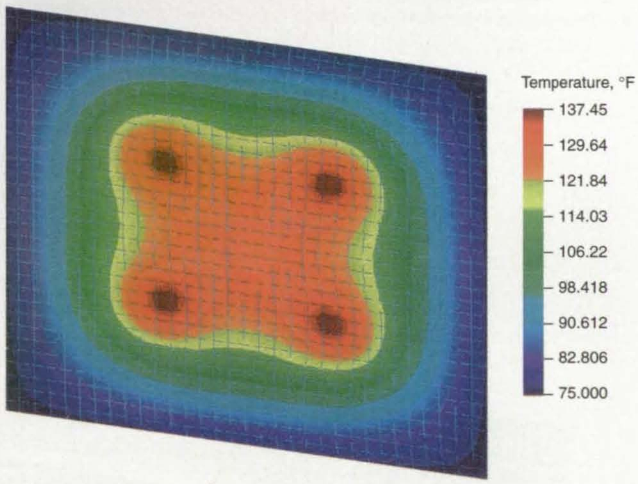
In one example in the CTE-mismatch analysis, the effective CTE of the region of a carbon-fiber-core where flip chips would be mounted was found to be $\approx 1.0 \times 10^{-5}$ (°C)$^{-1}$; in contrast, the corresponding CTE of a conventional FR-4 PWB was found to be $\approx 2.1 \times 10^{-5}$ (°C)$^{-1}$. Thus, the carbon-fiber core exhibits less CTE mismatch with the chip substrate material — silicon — for which the CTE ranges from 3×10^{-6} to 5×10^{-6} (°C)$^{-1}$. Ultrasonic imaging of carbon-fiber-core FCOB specimens after thermal tests of the specimens revealed that the thermal tests did not result in any detectable increase in the incidence of failures of flip-chip-mounting solder joints.

This work was done by Eyan Lee and William E. Davis of Applied Material Technologies, Inc., for **Glenn Research Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16890.



TEMPERATURE MAP FOR CONVENTIONAL PWB



TEMPERATURE MAP FOR PWB WITH CARBON-FIBER CORE

These **Temperature Maps** were computed in a finite-element simulation of thermal conditions on a PWB on which four heat-generating flip chips are mounted. For each of the two cases shown here, the peak temperature mentioned in the text was calculated as an average over all nodal values within the "footprints" of the flip chips.

Lightweight, Dimensionally Stable Printed-Wiring Boards

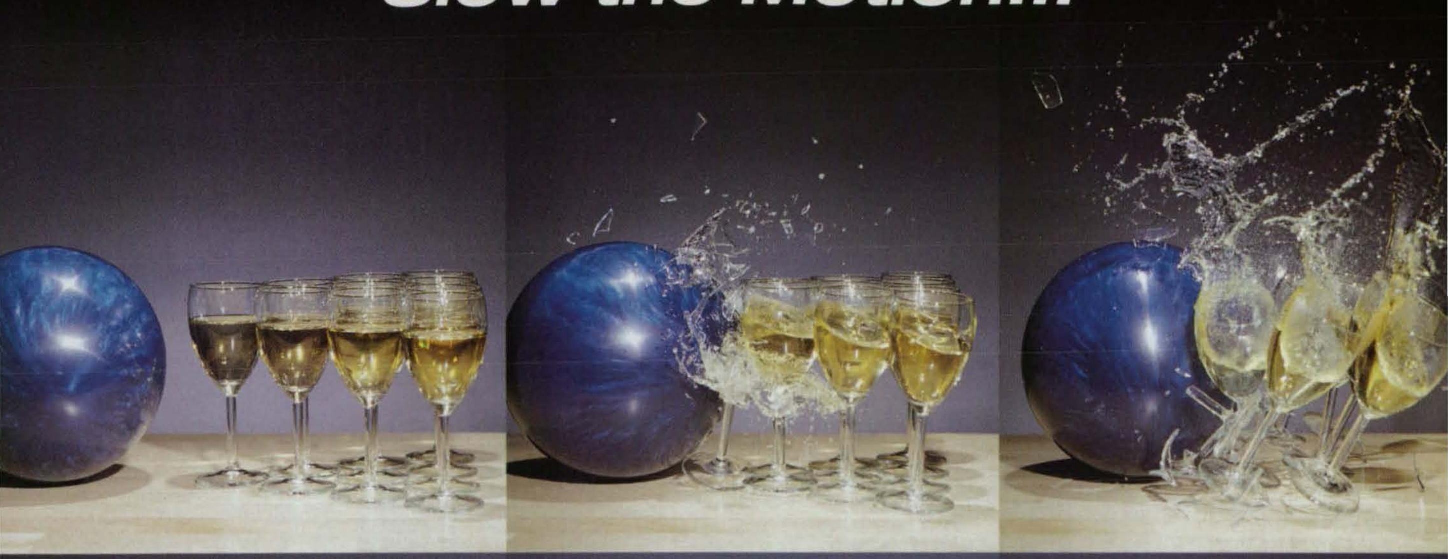
In comparison with traditional PWBs, these offer better heat dissipation and CTE matching.

John H. Glenn Research Center, Cleveland, Ohio

Printed-wiring boards (PWBs) that are especially suitable as substrates for highly reliable, lightweight electronic circuits for aircraft and spacecraft have been developed. Like traditional PWBs, these PWBs are laminated composites that include dielectric inner layers plus copper outer layers that can be etched to form signal and power conductors. Going beyond the designs of traditional PWBs, these PWBs include multiple copper layers separated by dielectric (e.g., polyimide) layers, plus inner cores that contain carbon cloth.

(Continued on pg. 48)

Slow the Motion...



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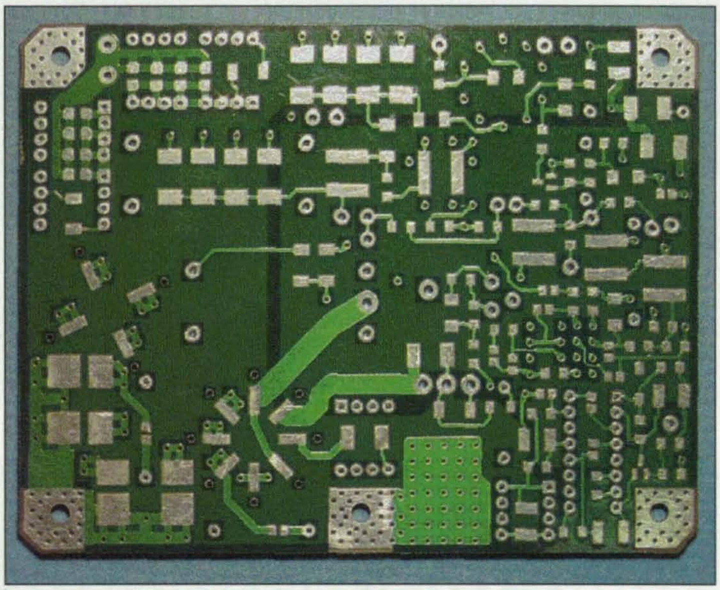
These PWBs are intended to accommodate high densities of electronic components and of interconnections among them. The designs of these PWBs can be optimized to satisfy several requirements, including removal of heat generated in electronic components, maximization of stiffness with minimization of weight, and minimization of mismatches between the coefficients of thermal expansion (CTEs) of the PWBs and the components (e.g., leadless chip carriers) mounted on them. Previous solutions to the heat-dissipation and CTE problems have included the use of copper/Invar/copper (CIC) cores. While CIC cores contribute to reduced CTEs and increased thermal conductivities, they also contribute to increases in weights and costs.

Carbon cloth is used in the core layers of the present PWBs because it affords a combination of properties (low CTE, high thermal conductivity, low mass density, and high stiffness) that help to satisfy the requirements mentioned above. [The use of carbon cloth in the core layers of PWBs for this reason is reported in the preceding article, "Mounting Flip Chips on Heat-Dissipating, Matched-CTE Boards" (LEW-16890).] The present carbon-core PWBs offer the advantages, but not the disadvantages, of PWBs with CIC cores; that is, unlike those with CIC cores, these are lightweight and relatively inexpensive. Because of its superior heat-dissipating and CTE characteristics, a PWB of this type (see figure) can accommodate about 40 percent more electronic components than can a traditional PWB.



This **PWB Contains a Carbon-Cloth Core** and a total of eight copper layers. The overall dimensions of the board are approximately 3.25 by 4.25 in. (about 8.3 by 10.8 cm).

This work was done by Richard A. Bohner and William E. Davis of Applied Materials and Technologies, Inc., for **Glenn Research Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16648.

Protective Solid Electrolyte Films for Thin Li-Ion Cells

These films would simplify fabrication and afford greater flexibility in design.

NASA's Jet Propulsion Laboratory, Pasadena, California

Thin films of Li_2CO_3 are under consideration for use as passivating layers between electrodes and solid electrolytes in advanced thin-film lithium-ion electrochemical cells. By suppressing undesired chemical reactions as described below, the Li_2CO_3 films could help to prolong the shelf lives, increase the specific energies, and simplify the fabrication of the cells. Batteries comprising one or more cells of this type could be used as sources of power in such miniature electronic circuits as those in "smart" cards, implantable electronic medical devices, sensors, portable communication devices, and hand-held computers.

The need for passivation arises as follows:

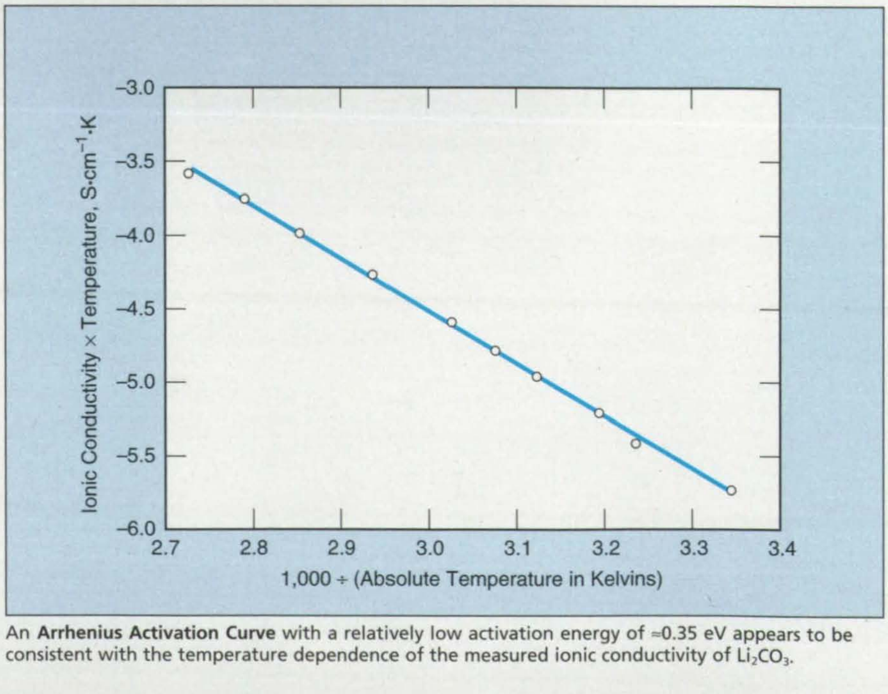
- A state-of-the art thin-film Li-ion cell typically consists of a lithium metal anode, a glassy solid electrolyte, and a cathode made of a lithiated transition-metal oxide (e.g., $LiCoO_2$). The Li anode and most solid electrolytes are very sensitive to humidity. To prevent destruction of the anode and solid-electrolyte films by reactions with airborne moisture, it is necessary to adhere to strict handling procedures during fabrication; in particular, the electrode and electrolyte films must be handled in a glove box. As a consequence, the overall process of fabrication of thin-film Li-ion cells and batteries is more complex than it would otherwise be.
- Many solid electrolytes are not chemically or electrochemically stable when in contact with Li or when exposed to high charging potentials. Intermediate passivating films that could protect such solid electrolytes at the anode and cathode potentials would be very desirable.

The selection of materials for thin-film Li-ion batteries involves concerns similar to those for conventional bulk Li-ion batteries. However, the techniques used to fabricate thin-film batteries offer distinct advantages over those used to fabricate conventional batteries by affording the flexibility to design cells with multilayer thin-film structures that can be made to exhibit properties not attainable in bulk structures. As an especially relevant example, a thin-film electrolyte structure can comprise a film of a high-ionic-conductivity material coated with a film of a material of lower ionic conductivity but greater stability versus Li. The development of films that can provide stability at anode and cathode potentials enables the use of many electrolyte materials, including both novel electrolytes and electrolytes that were known previously and were considered unusable because of poor chemical or electrochemical stability.

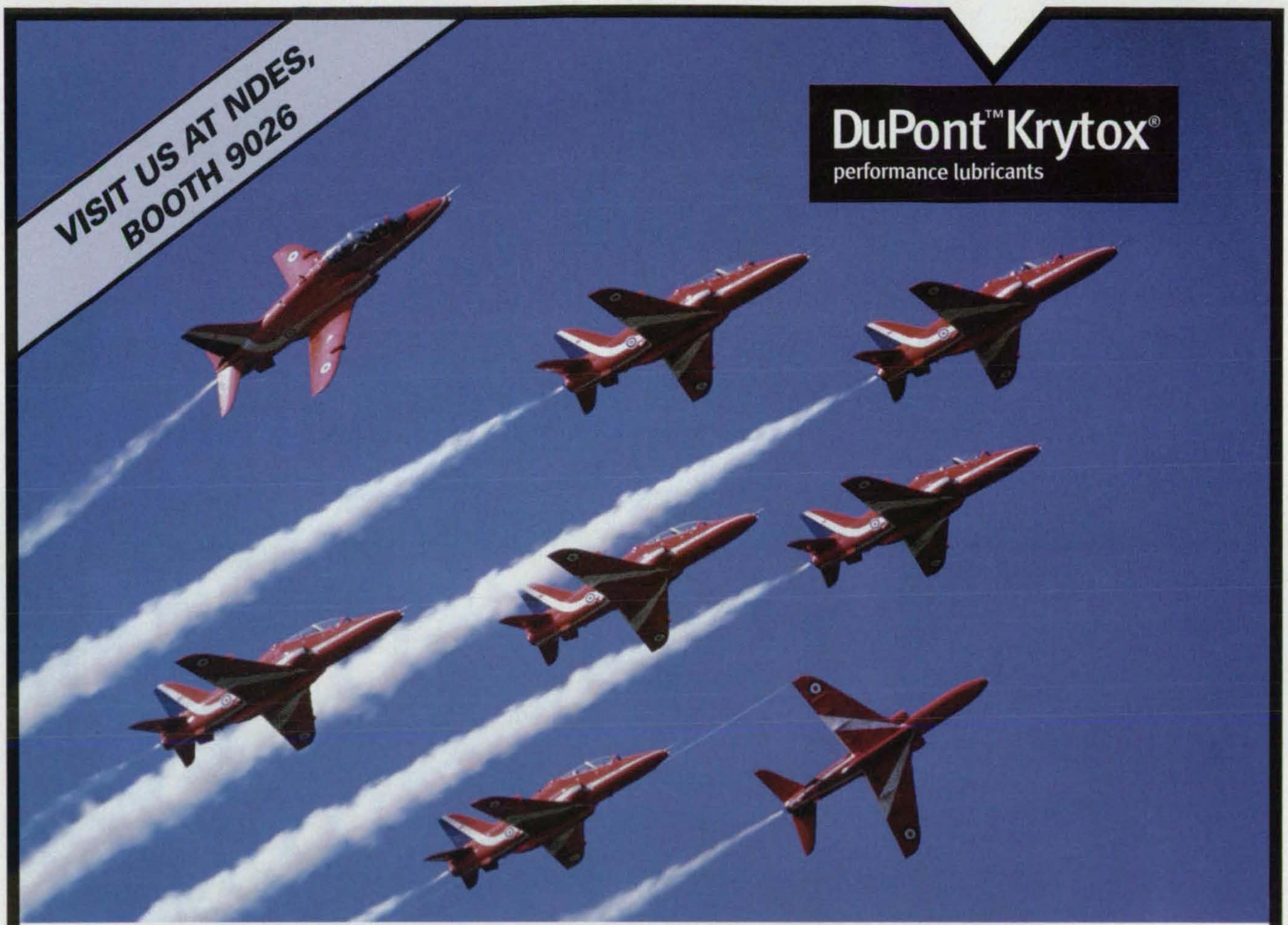
Li_2CO_3 is electronically insulating and somewhat ionically conductive. In research conducted thus far, solid electrolyte films of Li_2CO_3 have been prepared by magnetron sputtering. These films have been found to be stable in air and to be useful for protecting components of Li-ion cells as described above. More specifically, the Li_2CO_3 films have been found to afford (1) excellent passivation against reactions between electrolytes and anodes; (2) excellent stability against oxidation at high voltage, as evidenced by the oxidative stability of carbonate-based liquid electrolytes at potentials up to 4.8 V, and (3) a high degree of stability in presence of humidity. The resistance to attack by airborne moisture is an important advantage in that during fabrication, air-sensitive components passivated by Li_2CO_3 can be moved between processing tools in ambient air.

In impedance-spectroscopy tests, Li_2CO_3 films sandwiched between Mo electrodes exhibited electrical characteristics similar to those of other solid electrolyte films. The room-temperature ionic conductivity of the $LiCoO_2$ was found to be rather poor ($\approx 5 \times 10^{-9}$ S/cm), though it was found to fit to an Arrhenius activation curve (see figure). Given this low ionic conductivity, Li_2CO_3 would likely not be suitable for main electrolyte layers, but would be better suited for thin passivating films.

This work was done by Ratnakumar Bugga and William West of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Materials category. NPO-20953*



An **Arrhenius Activation Curve** with a relatively low activation energy of ≈0.35 eV appears to be consistent with the temperature dependence of the measured ionic conductivity of Li_2CO_3.



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Study of Turbulent Boundary Layer on the F-15B Airplane

Automated hot-wire anemometry has been demonstrated in flight tests.

Dryden Flight Research Center, Edwards, California

NASA's F-15B #836 is a two-seat version of the F-15, which is a high-performance, supersonic, all-weather fighter airplane. The F-15B is used as a test-bed aircraft for a wide variety of flight experiments. In support of this use, a flight-test fixture (FTF) was developed to provide a space for flight experiments in a region with known aerodynamic conditions. The FTF is a fully instrumented test article mounted on the center line of the bottom of the fuselage of an F-15B airplane. The FTF includes an interchangeable experiment panel and is 107 in. (2.72 m) long, 32 in. (0.81 m) high, and 8 in.(20.3 cm) wide, with a 12-in. (30.5-cm) elliptical nose section. The FTF has been used in many flight experiments during the past several years and can be modified to satisfy a variety of research requirements.

One method of measuring turbulent fluctuations of density and velocity across the compressible boundary layer of an aircraft surface in flight (which fluctuations give rise to Reynolds stresses) involves the use of a recently developed automated hot-wire anemometry system. Prior to the development of the automated hot-wire anemometry system, a method of measuring turbulent velocity fluctuations in flight had not been perfected and routinely used in NASA's flight experiments, primarily because of the limitations of conventional anemometry systems. Conventional anemometry systems are characterized by difficulties in tuning, poor signal-to-noise ratios and low bandwidths at low overheat ratios, sensitivity to electromagnetic interference, and vulnerability to effects of cable capacitance. The automated hot-wire anemometry system is, more specifically, a constant-voltage anemometry (CVA) system that has been shown not to be subject to the aforementioned deficiencies of conventional anemometry systems. The CVA system was selected for flight testing on the FTF on the F-15B airplane.

It is essential to characterize the turbulent boundary layer in flight experiments because the length scales characteristic of turbulence in wind-tunnel experiments are significantly different from those of turbulence in flight. Thus, flight measurements in turbulent boundary layers are necessary for validation of computational fluid dynamics (CFD) computer codes and for predicting transitions from laminar to turbulent flow. The specific objective of

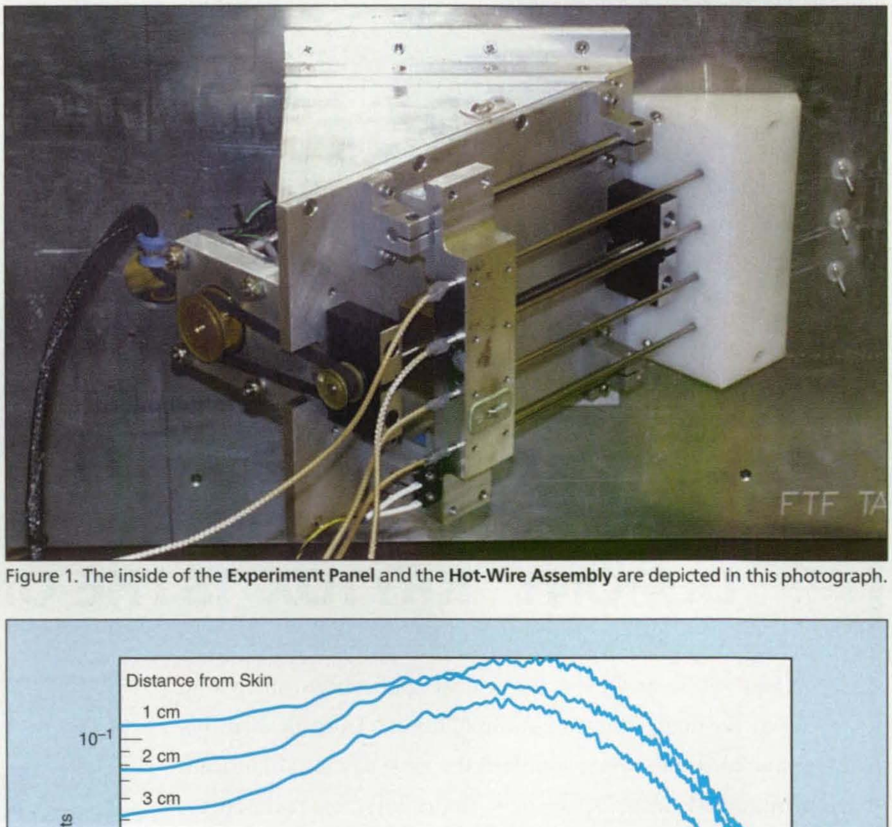


Figure 1. The inside of the **Experiment Panel** and the **Hot-Wire Assembly** are depicted in this photograph.

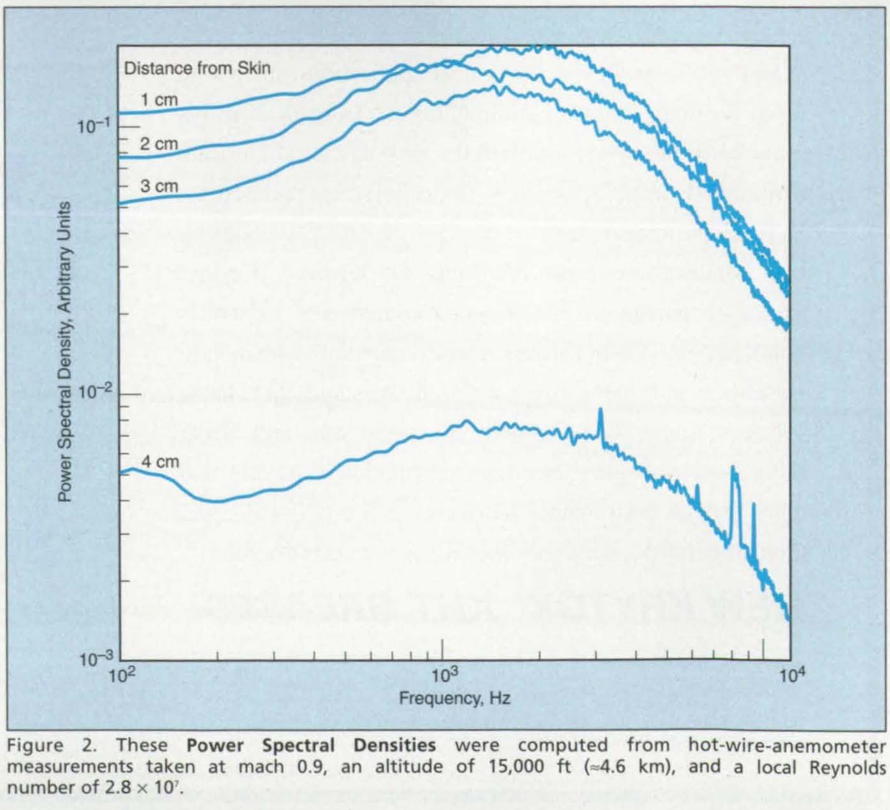


Figure 2. These **Power Spectral Densities** were computed from hot-wire-anemometer measurements taken at mach 0.9, an altitude of 15,000 ft (≈4.6 km), and a local Reynolds number of 2.8×10^7.

the flight tests was to validate the concept of CVA for measuring velocity fluctuations in turbulent boundary layers in flight.

The flight-tested CVA system included four hot wires (two wires of 5-μm and two of 10-μm diameter) mounted on probes on the aft panel of the F-15B FTF (see Figure 1). The measurements taken with the wires of each diameter were used to verify the sensitivity and repeatability of measurements. The hot-wire probes were mounted under the airfoil skin and were extended just prior to collection of data. The probes were extended at an angle of 45° into the boundary-layer flow to distances of 1, 2, 3, and 4 cm from the skin. Data were taken simultaneously for each wire during a time interval of 32 seconds at each flight condition. After collection of data, the probes were retracted. The associated electronic circuits, (including the power supply, CVA subsystem, and data-acquisition subsystem) were installed aboard the FTF.

In the tests, data were taken under various flight conditions ranging between mach 0.6 and mach 1.3 at an altitude of between 15,000 feet (≈4.6 km) and 30,000 feet (≈9.1 km). At the time of reporting the information for this article, analysis of the data was underway. Figure 2 presents a sample of processed data obtained from the flight tests. The raw data were sampled at a rate of 50 kHz and low-pass filtered at frequency of 20 kHz. The plots in Figure 2 show that there was significant turbulence at distances of 1, 2, and 3 cm from the skin. The turbulence was considerably lower at 4 cm from the skin, indicating the edge of the boundary layer. The peaks of the power spectral densities occurred at frequencies between 1,000 and 1,200 Hz. The turbulent energy cascade is clearly indicated, at frequencies above 12 kHz, by approximately constant negative slope at all four boundary-layer locations.

The turbulent data signals were analyzed to determine the degree to which they approximated Gaussian functions. Those obtained at the distances of 1 and 2 cm from the skin were found to be Gaussian, while changes from Gaussian to non-Gaussian were found to occur at distances of 3 and 4 cm.

This work was done by Angela K. Beaver and Donald S. Greer of **Dryden Flight Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*
DRC-01-15

Improved Alignment Mechanism for Robotic Drilling

The improved design prevents jamming of an alignment key in an incorrect position.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved alignment mechanism and mating procedure have been devised for a robotic drilling system in which there is a need to assemble drill stem rods for sampling soils and rocks on a distant planet or asteroid. This mechanism is applicable to systems requiring positive axial alignment between segments. Similar mechanisms could be used on Earth, not only for assembling long drills but also for any system where a series of rods must be robotically assembled, such as in truss construction.

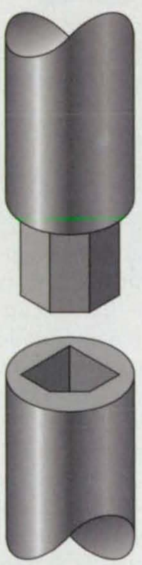


Figure 1. **Conventional Mating Schemes** incorporating polygonal configuration are susceptible to jamming.

Conventional robotically actuated drill-stem segmenting systems use alignment keys that often feature polygonal protrusions. Figure 1 shows a conceptual example. These mechanisms, while ensuring correct rotational alignment, are susceptible to jamming in a misaligned position. To prevent such jamming, complex control systems must be implemented that can provide fairly accurate alignment between the stem segments

prior to any mechanical engagement. Additional control must also be implemented to deal with the possibility that jamming occurs.

The improved alignment mechanism and mating procedure preclude any chance of jamming during assembly. The mechanism also does not require rotational alignment prior to engagement. The interface is a "half dog clutch," a mating scheme where two half cylinders are mated together (see Figure 2). However, the alignment keys are cut so as to produce a helical face. These keys are used for rotational alignment as well as torque transfer between segments. In the current implementation, an additional pilot is used to ensure axial alignment, but this feature may not always be necessary. The following steps are used to mate the segments:

1. The segments to be aligned are moved toward each other until contact between them is sensed. It may be beneficial to slowly rotate one of the rods in the direction opposite that of a flat cut that is part of the alignment key to help ensure that the helical faces of the dogs contact first.

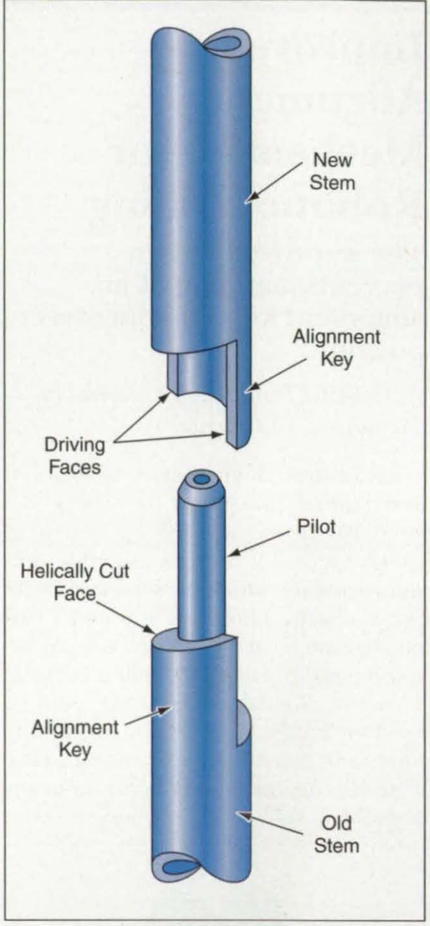


Figure 2. An **Improved Alignment Mechanism** does not require rotational alignment prior to engagement.

2. The rods are moved apart to a distance that is fraction of the height of the alignment key.
3. The rods are re-engaged by simultaneous rotation and translation in such a way that the tip of the alignment key travels parallel to the helical alignment-key surface. This motion ensures that next contact will be between driving faces, at which time positive axial alignment is achieved.
4. The axial-rotational movement can continue until full engagement of the segments is achieved and detected, assuming that one segment is held freely so that the other may drive it.

Note that for this entire process only two simple sensory inputs are required. At no point must the control system know the rotational position of either segment.

This work was done by Benjamin Dolgin and Stephen Askins of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*
NPO-21164

Measuring Volume of Incompressible Liquid in a Rigid Tank

The measurement is unaffected by the shape of the liquid or tank.

NASA's Jet Propulsion Laboratory, Pasadena, California

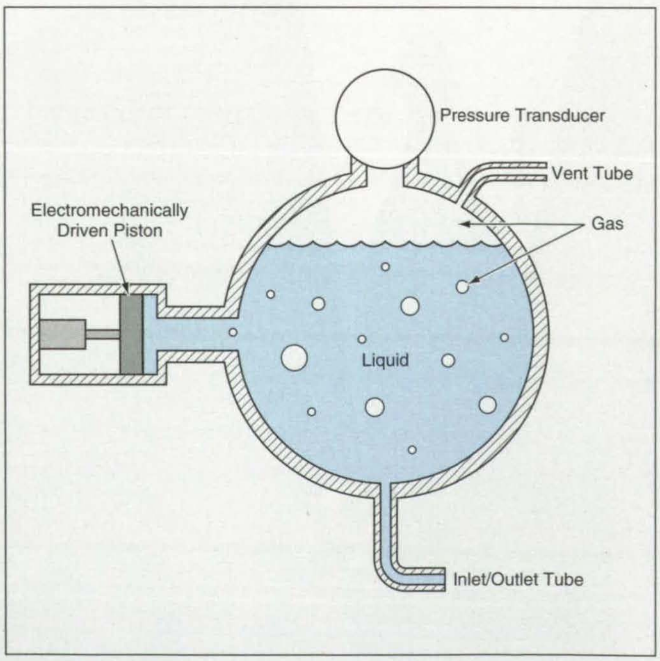
A technique for measuring the volume of an incompressible liquid in a rigid tank involves measurement of the total volume of gas in those parts of the tank not occupied by the liquid. The volume of liquid is then computed by subtracting V from the total volume of the tank and the associated plumbing.

Unlike liquid-level-measuring techniques, this technique works whether or not a gravitational field is present and is unaffected by the shape of the liquid or tank. Even if bubbles of gas are present in the liquid or if the liquid has broken up into separate globules or pools, the measurement of the total volume of gas is unaffected.

The pressure in the tank is measured while the total volume of the tank is varied by use of a piston or bellows (see figure). It is assumed that the gas is a noncondensible ideal gas, that the alternating compression and decompression of gas is adiabatic, and that the variation in volume is a small fraction of the total volume of gas. Under these assumptions, the total volume (V) of gas in the tank is given by $V = -\gamma P(\Delta V/\Delta P)$, where γ is the specific heat of the gas at constant pressure ÷ the specific heat of the gas at constant volume, P is the pressure, ΔV is the change in volume, and ΔP is the change in pressure that accompanies the change in volume. In a demonstration of this technique, the volume of water in a 94-liter tank was determined within 1 liter.

This work was done by Frank T. Hartley of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*

NPO-19211



The **Volume of Gas** (including bubbles) in the tank is determined by measuring the small change in pressure that accompanies a small change in volume. The volume of liquid is then computed by subtracting the volume of gas from the total volume of the tank and plumbing.

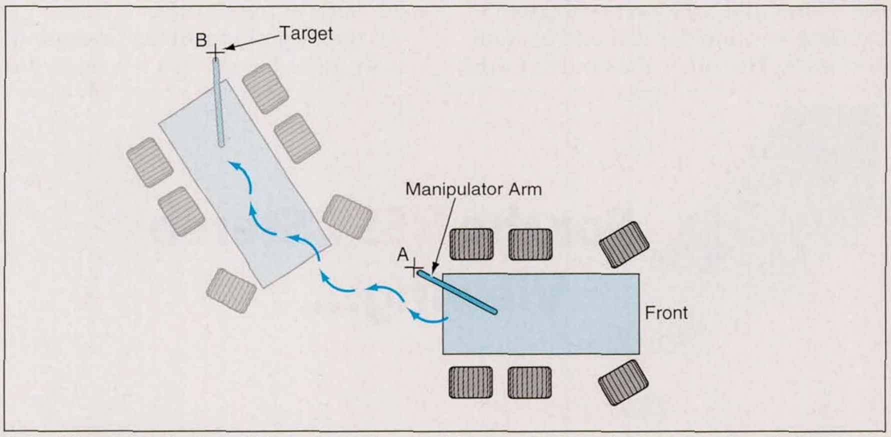
Machinery/Automation

Vision-Based Maneuvering and Manipulation by a Mobile Robot

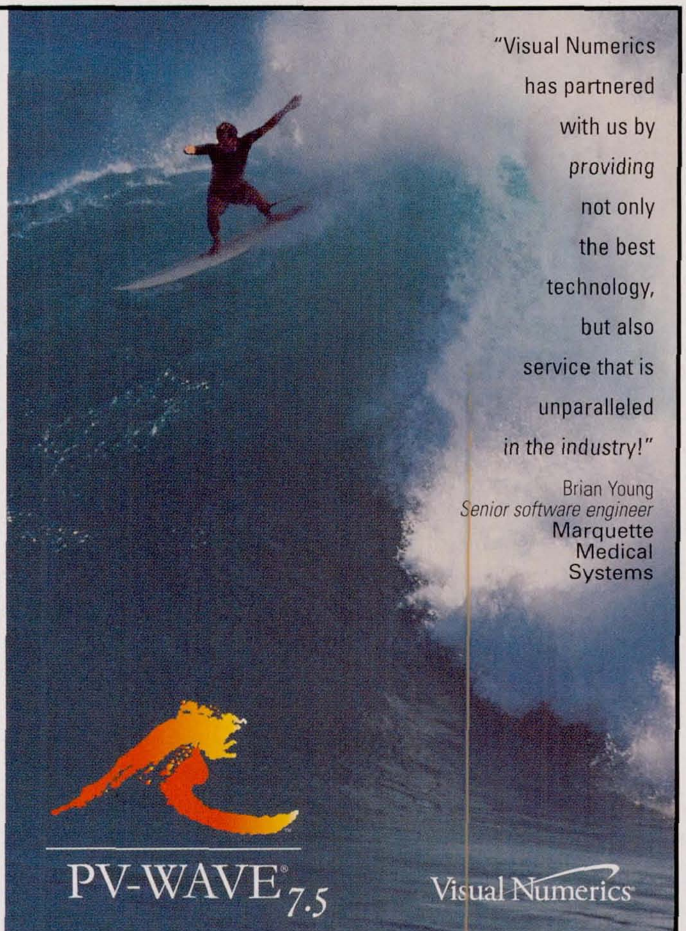
Mobility is used to augment limited dexterity.

NASA's Jet Propulsion Laboratory, Pasadena, California

A small mobile robot equipped with a stereoscopic machine vision system and two manipulator arms that have limited degrees of freedom has been given the ability to perform moderately dexterous manipulation autonomously, under control by an onboard computer. The approach taken in this development has been one of formulating vision-based control software to utilize the mobility of the vehicle to compensate for the limitation on the dexterity of the manipulator arms. Although the goal was selected visually, it is tracked onboard using information about its shape; in particular, the target is assumed to be a local elevation maximum (i.e., the highest point within a small patch of area).



A Six-Wheeled Robotic Vehicle Is Moved — in this case, backward along a series of circular arc segments — while visually tracking the target, so that the manipulator-arm workspace initially at position A can be robustly moved onto the target at position B.



The mobile robot in question is Rocky 7 — a prototype "rover"-type vehicle used in research on robotic-vehicle concepts for the exploration of Mars. The mobility system of Rocky 7 is based on a six-wheel-drive rocker-bogey mechanism that includes two steerable front wheels and four nonsteerable back wheels. One of the manipulator arms is equipped with two independently actuated scoops for acquiring samples. Not counting the motions of the scoops, this arm has two degrees of freedom — shoulder roll and a shoulder pitch. The other manipulator arm is a mast on which is mounted a stereoscopic pair of video cameras and that can, if desired, be tipped with a scientific instrument. The mast has three degrees of freedom (shoulder pitch, shoulder roll, and elbow pitch). The mast can be used to position and orient its cameras and/or to place its tip instrument on a target object to acquire a sample or take a reading. Additional stereoscopic pairs of cameras are located at the front and rear ends of the main body of the vehicle.

At the beginning of an operation, one or more target objects a small distance away are selected, and then the robot is commanded to perform autonomously some manipulations that involve the objects. Following the basic approach of using mobility to augment dexterity, the navigation and mobility control subsystems of the vehicle cause the vehicle to maneuver into a position and orientation in which the target lies within the range of one of the manipulators (see figure), and then the manipulator control subsystem causes the manipulator to perform the remaining fine positioning and manipulation.

The key to ensuring that the rover reaches its target is to move in small steps, and lock onto the target by automatically tracking its shape. The computer processes the image data from the stereoscopic camera pairs into an elevation map of the nearby terrain and locates the target on the elevation map. The computer plans the route of the vehicle across the terrain toward the target, using an approximate kinematical model (assuming flat terrain and no slippage of wheels). At frequent intervals along the route, updated elevation maps are generated from newly acquired stereoscopic-image data, the target is identified on the updated maps, and the planned route is corrected accordingly. Here the scale-invariant features (i.e., shape, elevation, and centroids) are tracked: this allows one to track the target even as its image grows dramatically in size during the final approach, a situation that often causes traditional visual servoing techniques to fail. This process of iterative, vision-based refinement of the route continues until the vehicle arrives at the desired location near the target.

Once the vehicle is in the desired position and orientation relative to the target, the designated manipulator arm is lowered toward the target; tactile sensing is used to signal contact with the target or with the ground adjacent to the target. The manipulator arm is then commanded to perform the assigned manipulation. Manipulations that Rocky 7 has performed in demonstrations include grasping several small rocks that were initially at a distance of >1 m and placing an instrument on a boulder that was initially at a distance of >5 m.

This work was done by Mark Maimone, Issa Nesnas, and Hari Das of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at*** ***www.nasatech.com/tsp*** *under the Machinery/Automation category.*

NPO-21011

Photolithographic Fine Patterning of Difficult-To-Etch Metals

Copper is used as a liftoff material.

John H. Glenn Research Center, Cleveland, Ohio

A process that includes photolithography, liftoff, etching, and sputter deposition has been developed to enable the fabrication of thin, finely patterned layers of gold, platinum, and other difficult-to-etch materials in advanced miniature sensors and associated electronic circuitry. Heretofore, photolithography has been used in conjunction with liftoff and etching to produce finely detailed structures in easy-to-etch materials. The present process is needed because conventional photolithography cannot be used to pattern difficult-to-etch materials and the alternative processes heretofore available for patterning difficult-to-etch materials are limited to spatial resolution of about 0.005 in. (≈0.13 mm) or coarser.

The process (see figure) includes some new steps plus some steps from prior processes that are used with modifications and in a different sequence. The sequence is the following:

1. Copper is deposited over an entire face of a substrate of suitable material (e.g., alumina). If the substrate material is one to which copper does not adhere well, aluminum or nickel can be used instead of copper. The thickness of the copper (or aluminum or nickel, as the case may be) should be made roughly three times that of the final desired difficult-to-etch metal layer.
2. The copper is covered with positive photoresist.
3. The photoresist is soft-baked.
4. The photoresist is exposed through a photomask in the desired pattern.
5. The photoresist is developed.
6. It is hard baked at 110 °C for 30 minutes.
7. The entire workpiece is washed with a half-and-half mixture of nitric acid and water to remove the copper from the regions in which the difficult-to-etch metal is to be deposited. This removal of copper is facilitated by a slight undercutting of the photoresist.

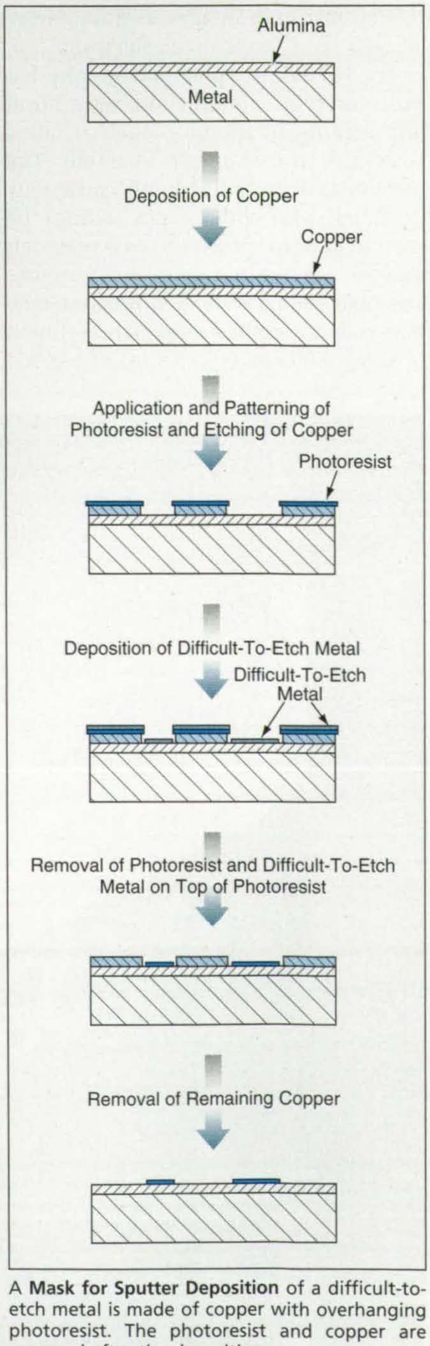
The most significant aspect of this process is the use of copper as the liftoff material. Partly because of the rapidity with which copper is etched, it is possible to control the amount of undercutting of the photoresist and to

ensure that the undercutting occurs uniformly and cleanly. Undercutting is very important to the success of this process: it expedites removal of unwanted material later in the process and increases the sharpness of the final pattern of difficult-to-etch metal.

8. The substrate holder is precooled to 10 °C before the piece is loaded into the sputtering system.
9. The difficult-to-etch metal is sputter-deposited at a relatively low power density (0.14 W/cm^2) over the entire substrate. In the regions from which the copper and photoresist were previously removed, difficult-to-etch metal becomes deposited directly onto the substrate. During the deposition of the difficult-to-etch metal, the substrate is cooled to prevent the carbonization of the photoresist; this is necessary because carbonization would make the subsequent removal of the photoresist more difficult.
10. The workpiece is washed with acetone to remove all the photoresist plus the portion of difficult-to-etch metal deposited on top of the photoresist.
11. The workpiece is washed with the nitric acid/water mixture to etch away all the remaining copper, leaving the desired difficult-to-etch metal pattern.

This work was done by Charles A. Blaha of Akima Corp. for **Glenn Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Manufacturing category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17079.



A **Mask for Sputter Deposition** of a difficult-to-etch metal is made of copper with overhanging photoresist. The photoresist and copper are removed after the deposition.

Software for Optimized Flattening From 3D to 2D

Manufacturing considerations can be taken into account in designing minimally wasteful 2D patterns.

John H. Glenn Research Center, Cleveland, Ohio

A computer program offers enhanced capabilities for calculating two-dimensional (2D) patterns needed to construct specified three-dimensional (3D) surfaces to within acceptably close approximations, with minimal waste of sheet material. Examples of complexly shaped sheet-material items that could be designed by use of this program include aircraft fuselages, hulls of ships, clothing, and automotive bodies.

This program offers two advantages over the flattening subprograms of prior computer-aided-design, computer-aided manufacturing (CAD-CAM) programs:

- The program utilizes all available pertinent information, including not only information on the desired 3D shape but also information about the manufacturing process in which the two-dimensional pattern(s) would be formed into the 3D surface. The more information about the 3D surface and the manufacturing process that is available, the better can be the match between the 3D surface and the 2D pattern(s) used to construct it.
- The program affords options that enable the user to define and build a method of solution based on the unique characteristics of, and the available data about, the 3D surface. In particular, the program can implement any or all of four independent procedures, and for each procedure there is a choice of several algorithms. This array of options enables the user to integrate any available pertinent information into the solution via at least one procedure.

In the event that the desired 3D surface is one that can be fabricated by bending only (such a surface is termed "developable" in the art) then procedures 1 and 2 are the only ones needed. However, if in-plane deformations (stretching or shrinking) are needed, or if there is a need to fold any portion of sheet material upon itself to form multiple layers, then procedure 3 or procedures 3 and 4 must also be used.

In procedure 1, boundaries that divide a 3D surface into regions are placed into a plane. Because the algorithms defining these boundaries can be chosen from a library of algorithms, these boundaries serve as initial conditions which help define a unique flattening process. The placement of these boundaries depends on several factors unique to the 3D surface. One factor, which can be controlled by placement of the boundaries, is to allow or not allow distortions to move from one 2D region into another 2D region. Also, the user might want to satisfy some general 2D outer-boundary constraints, which can be addressed only at the boundary-placement level. Some 3D surface boundaries cannot be placed directly into the 2D plane by procedure 1. Such a boundary is not amenable to placement by use of one or two algorithms alone; instead, it is necessary to "grow" the boundary into the 2D plane during the execution of procedure(s) 2, 3, and/or 4.

In procedure 2, 3D cell walls are placed into the plane, such that the lengths of the 3D arcs of each cell wall are preserved in the plane. At this point, the program is working in the 2D plane but is using information which geometrically defines the corresponding 3D surface triangle. After procedure 2 has been performed at the local level on an individual cell, the user is then given the option of using either procedure 3 or procedures 3 and 4. These two procedures involve the relationship between the area and geometry of a 3D cell and the area and geometry of the corresponding recently formed 2D cell. In particular, if the user knows there was a local expansion, contraction, or folding of the 2D sheet during the manufacturing process, then procedure 3 or procedures 3 and 4 must be used. These procedures modify the local 2D cell by incorporating, into the 2D cell, the inverse stresses and strains inherent in the manufacturing process of forming a 3D surface from a 2D surface. Procedure 4 is used and coupled to procedure 3 if the expansion or contraction factors are associated with preferred directions.

Another important element of the program logic is the coupling of procedure 2 directly to procedure 3 by feeding the geometric solution of procedure 2 into procedure 3. The geometric solution from procedure 2 serves as an initial geometry from which procedure 3 (or 3 and 4) can geometrically and algebraically iterate. During this iteration, the 3D cell is transformed from a predefined 3D cell geometry to a 2D cell geometry which satisfies input data defining the manufacturing process.

This work was done by Bruce M. Auer of **Glenn Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Manufacturing category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17029.

Electron-Beam Welding of Superalloys at High Temperatures

Strain age cracks can be prevented.

John H. Glenn Research Center, Cleveland, Ohio

Electron-beam welding at high temperatures has been found to be a suitable process for joining structural components made by casting certain superalloys. This process can be used in the fabrication of superalloy parts that must withstand high operating temperatures. Examples of such parts include exhaust ducts of advanced aerospace engines and end caps on turbine buckets.

The superalloys in question are γ'-strengthened nickel-base alloys that contain either >3 weight percent Al or >6 percent Ti. Strain age cracks form in such alloys upon cooling after welding or on subsequent reheating to aging temperatures. The cracks result from a combination of residual stresses produced during welding and aging cycles. Heretofore, the formation of the strain age cracks has made it impossible to utilize these superalloys to make welded structures.

The development of the present process brought electron-beam welding together with vacuum heat treatment to provide a new industrial capability. Electron-beam welding has long been used to produce structural weldments in a wide variety of alloys, but, heretofore, has not been successful for welding nickel-base superalloy structures. Nickel-base superalloys are frequently heat-treated in vacuum furnaces to impart the very properties for which they were selected.

In the present process, a heat-treating furnace is placed in the vacuum chamber of an electron-beam welding machine. A superalloy structure to be welded is placed in the furnace. Prior to and during welding, the furnace is used to heat the entire superalloy structure to a temperature at or near the solution temperature of the alloy. Maintaining the entire structure at this temperature reduces or eliminates the thermal stresses produced by the differential thermal expansion during welding. Further, maintaining this temperature for a while after welding affords some relief of solidification stresses, thereby helping to prevent subsequent strain age cracking. The structure can then be cooled rapidly and later aged or can be aged during the cooling cycle after welding has been completed. An additional advantage is that the reduction in thermal stress prevents the formation of liquation cracks in the heat-affected zones of the welds.

This work was done by Thomas J. Kelly of General Electric Co. for **Glenn Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Manufacturing category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16686.

Petri-Dish Spreaders Sterilized by Electrical Heating

Sterilization is faster, easier, and less expensive than it is for conventional glass spreaders.

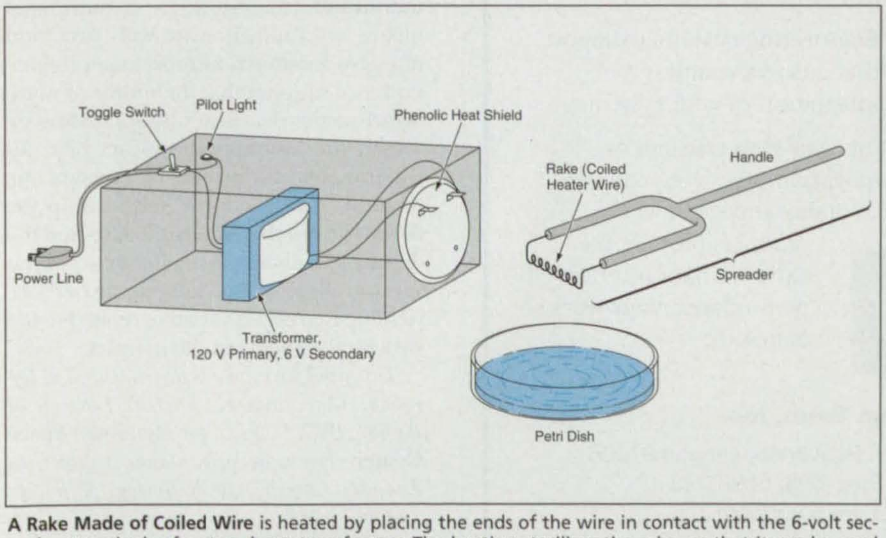
Lyndon B. Johnson Space Center, Houston, Texas

An improved method of sterilizing petri-dish spreaders and a spreader design to implement the method have been developed. In comparison with the conventional methods of sterilizing petri-dish spreaders, the improved method is expected to prove easier, safer, less time-consuming, and less costly, and to require less laboratory space. This improved method could be used in microbiological investigations in microgravity (e.g., aboard the International Space Station) or in normal Earth gravity (e.g., in government and clinical laboratories and research institutions). Particularly, when used in spaceflight, the improved method will prove safer than the traditional flame sterilization method.

The prior art in the design, use, and sterilization of petri-dish spreaders is relatively straightforward. A conventional petri-dish spreader is a glass rod bent like a hockey stick. The longer straight segment of the rod is used as a handle, while the shorter straight segment is used to spread a suspension of micro-organisms with a small volume (typically 0.1-mL) evenly over the surface of the growth medium in a petri dish. After a suitable incubation time, colonies of the microbes grow on the surface of the medium. Provided that a known volume of a microbial suspension is spread evenly over the medium, an accurate count can be made, and the types of organisms in the suspension can be identified. If the suspension is not spread correctly, the growing colonies converge and become so crowded that it is hard to see the boundaries between them.

Each time a suspension of micro-organisms is spread over a different dish, a sterile glass spreader must be used. A spreader that was used on another dish can be reused if it is dipped into 95-percent ethyl alcohol and the alcohol is then ignited with a flame to sterilize the spreader. If multiple dishes are to be inoculated and insufficient time is available for sterilization of a single spreader between dishes, then multiple sterile spreaders must be prepared in advance, and considerable laboratory space must be allocated for storing them. Moreover, the use of alcohol and an open flame to sterilize spreaders introduces a fire hazard.

In the improved method, the spreader comprises a forked handle and a rake made of a coil of chromel electrical-resistance heater wire (see figure) that draws



A Rake Made of Coiled Wire is heated by placing the ends of the wire in contact with the 6-volt secondary terminals of a step-down transformer. The heating sterilizes the rake, so that it can be used to spread micro-organisms over a petri dish.

a current of 3 A when a potential of 6 V is applied. All that one need do to sterilize the rake is to place the end terminals of the wire in contact with the output terminals of a 6-V power source, which can be the secondary terminals of a 120-to-6-V step-down transformer. In this method, one does not attempt to sterilize the entire spreader; only the rake is sterilized. Tests have shown that the rake becomes heated to sterilizing temperature within only 2 to 3 seconds of heating at 6 V. After electrical heating, the rake can be cooled quickly on a damp sterile pad and is then ready to use. The sterility of the spreader in this improved method has been verified by extensive testing involving spreading on sterile media after spreading 0.1 mL of a bacterial solution on a petri dish.

The improved method has proved to be very reliable. Although it involves heat, this method, unlike the flame sterilization method, does not involve either alcohol or an open flame, and thus introduces less of a fire hazard. Because this method makes it unnecessary to use multiple presterilized glass spreaders, it reduces (relative to the flame sterilization method) the amount of storage space needed. Because sterilization and cooling before each use take only a few seconds in this method, preparation time is reduced, relative to that of the flame sterilization method. A further advantage of this method is that, because of its simplicity, little (if any) maintenance is needed.

This work was done by Duane Pierson of **Johnson Space Center** *and Thomas C. Molina of KRUG Life Sciences. For further information contact the Johnson Technology Commercialization Office at 281-483-3809.*
MSC-22903

Quantifying Microbial Diversity Through Dilution/Extinction

John F. Kennedy Space Center, Florida

A method of relatively easily, rapidly, and inexpensively quantifying the structural diversity of a multiple-species community of micro-organisms is based on the rate of extinction of phenotypic traits across a dilution gradient of a sample of the community. In this context, the concept of structural diversity encompasses the number (richness) and distribution (evenness) of separate or interacting biological entities responsible for given functions within the overall set of functions performed by the community. It is assumed that the rate of loss of character (as measured through testing for a given function) from the community upon dilution/extinction is proportional to the diversity of biological entities in the community. This assumption should be true as long as the average metabolic versatility of individuals (the width of a nutritional niche) does not increase with structural diversity. Inasmuch as most experimental evidence suggests that the widths of nutritional niches decrease with increasing diversity, the assumption appears valid. In experiments performed to evaluate the method, the nonlinear relationship between the number of positive tests and the density of cells across a dilution series was successfully fit to a rectangular hyperbola, yielding regression variables related to the structural diversity of the samples.

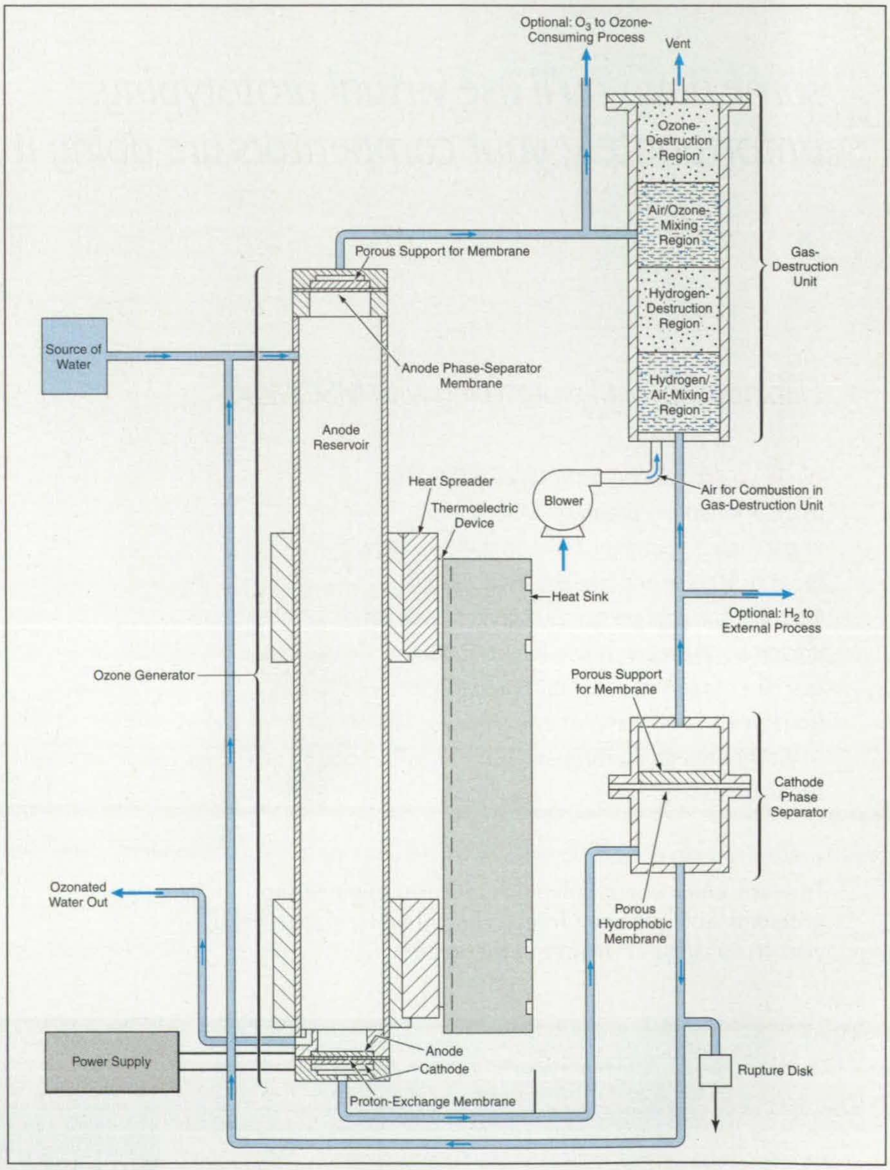
This work was done by Jay Garland of Dynamac Corp. and R. Michael Lehman of Bechtel BWXT, LLC for **Kennedy Space Center.** *For more information, contact the Kennedy Commercial Technology Office at 321-867-6224.*
KSC-12226

Electrochemical Systems Generate Ozone and Ozonated Water

The only inputs needed are electric energy and mildly pressurized water.

Lyndon B. Johnson Space Center, Houston, Texas

Improved electrochemical systems for generating ozone (in gaseous form and/or dissolved in water) have been invented for use in disinfection and in industrial processes in which the unique, highly oxidizing chemical properties of ozone are needed. More accurately, these systems generate oxygen along with high (relative to prior systems) concentrations of ozone and, optionally, with hydrogen as a byproduct. These systems contain no pumps and very few moving or wearing components, and the only inputs needed to operate these systems are electric energy and water supplied at mild pressure. Moreover, these systems can readily be designed and con-



This **System Adds Dissolved Ozone** to a stream of water. The system also generates hydrogen and O_2/O_3 mixture as optional byproducts.

structed on any scale (e.g., from research laboratory to industrial) to suit a wide variety of applications.

A basic system of this type (see figure) includes a power supply, an ozone-generator/anode-reservoir unit, a cathode phase separator, and a gas-destruction unit. At the bottom of the anode reservoir lies the active part of the ozone generator, which preferably is an electrolytic cell that contains a proton-exchange membrane with a porous anode on its upper face and a porous cathode on its lower face. A catalyst on the anode promotes the electrolytic production of oxygen and ozone, some of which dissolves into the water in the anode reservoir. The anode reservoir also serves as part of a liquid/gas separator, wherein oxygen and ozone generated at the anode form into bubbles or diffuse from the water and rise to the top of the reservoir. The rest of this phase separator is a hydrophobic membrane at the top of the reservoir that allows the O_2 and O_3 gases, but not water, to pass through to the top side. The mixture of O_2 and O_3 gases can be fed either to an O_3-consuming process or to the gas-destruction unit.

A tube connects the cathode with the cathode phase separator. A hydrophobic membrane in the cathode phase separator allows hydrogen gas, but not water, to pass through to the top side. Hydrogen gas from the dry (top) side of the membrane is either sent to the gas-destruction unit or discharged to a hydrogen-consuming external process. Preferably, water that has been transferred from the anode to the cathode by electroosmosis is returned from the bottom of the cathode phase separator to the input (top) end of the anode reservoir through the tube depicted as the longest in the figure.

The source of water is connected directly to the anode reservoir. The liquid/gas-separator membranes make it possible for the water from the source to displace any gases from anode reservoir and from the lower compartment of the anode phase separator. Once these gases have been displaced, the water comes into direct contact with these membranes and the transfer of water ceases as the pressures in the anode reservoir and cathode phase separator equalize with the pressure in the source of water. Provided that the pressure in the source equals or exceeds the pressure in the anode reservoir, the anode reservoir and the cathode phase separator remain full of water during all phases of operation.

Preferably, a cooling unit (e.g., comprising heat spreaders, thermoelectric devices, and a heat sink) is attached to the anode reservoir to remove waste heat and to chill the reservoir in order to reduce the rate of degradation of dissolved ozone and increase the solubility of ozone in the water. The output stream of ozonated water is taken from just above the anode at the bottom of the anode reservoir.

The gas-destruction unit includes a source of combustion air, a hydrogen/air-mixing region, a hydrogen-destruction zone that contains a hydrogen/air-combustion catalyst, an air/ozone-mixing region, and an ozone-destruction region that contains an ozone-destruction catalyst. The products of the gas-destruction unit are vented and/or drained.

This work was done by Oliver J. Murphy, Craig C. Andrews, and Thomas D. Rogers of Lynntech, Inc., for **Johnson Space Center.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to MSC-23046, volume and number of this NASA Tech Briefs *issue, and the page number.*

Solar Simulator for a Portable Solar-Absorptance Instrument

The principal advantages are portability and accurate normalized AM0 spectrum.

John F. Kennedy Space Center, Florida

A special-purpose solar simulator includes (1) a tungsten lamp that serves as a gray-body radiator with a temperature of 3,200 K and (2) a mosaic of filters such that the filtered lamp output has the same normalized spectral irradiance as that of sunlight outside the atmosphere of the Earth. This solar simulator is intended for use as the illuminator in a portable instrument that measures solar absorptances and total emittances of samples of materials.

The extra-atmospheric sunlight spectrum [also known as the airmass zero (AM0) spectrum] in question is the one described in standard E490-73a of the American Society for Testing and Materials (ASTM). The present solar simulator was developed because previously developed solar simulators are unsuitable for a variety of reasons: some do not cover the wavelength range (300 to 2,800 nm) required in the design specification for the instrument, some are too power-hungry and/or not durable enough for inclusion in a portable instrument, and some deviate too much from the ASTM standard.

The mosaic of filters includes commercially available filters plus a keystone filter developed specifically for this application. The mosaic was designed by use of a mathematical model based on the transmittance characteristics of the filters. The model was evaluated against optical "bread board" measurements. Areas, overlaps, and other design parameters were determined for the finished filter configuration.

A prototype instrument was built for proof of design. All design specifications relating to the filter were met: The filtered lamp output covers the spectral range from 300 to 2,800 and agrees more than 95 percent with the ASTM standard sun. Solar-absorptance measurements taken by the instrument are characterized by errors with magnitudes of less than 3 percent (that is, within a range of ±3 percent) of total absorptance.

The major benefit afforded by the design of this solar simulator is portability arising from low power consumption (relative to other solar simulators) and robustness. In addition, the compactness of the solar simulator (relative to other solar simulators) made it possible to integrate both the measurement of solar absorptance and the measurement of emittance into a single instrument package, whereas it would otherwise have been necessary to package them as separate instruments. Other benefits afforded by the design of the overall instrument are that a measurement can be made in <1 minute, and the instrument is more economical than are spectroradiometric systems.

The original intended use of the instrument is in measuring the radiative properties of components of the International Space Station. The instrument could also be used to measure the radiative properties (especially with respect to thermal radiation) of coatings and other materials, particularly in the aerospace industry.

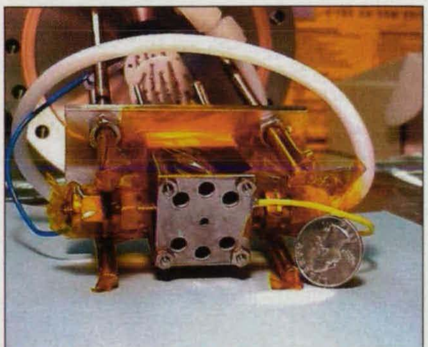
This work was done by David G. Crandall and John S. Harchanko of AZ Technology, Inc., for **Kennedy Space Center.** *For more information, contact the Kennedy Commercial Technology Office at 321-867-6224.*
KSC-12069

Portable Instrument Detects Very Dilute Airborne Organics

This instrument offers an attractive alternative to GC/MS.

NASA's Jet Propulsion Laboratory, Pasadena, California

A small, lightweight, low-power instrument, denoted a proton-transfer-reaction/ion-mobility spectrometer (PTR-IMS) has been developed for detecting airborne organic compounds at concentrations in the sub-parts-per-billion range. Instruments like this one could be used on distant planets (such as Mars) to search for trace organic compounds indicative of life as well as numerous potential terrestrial uses: A few examples include medical applications (e.g., analyzing human breath to detect compounds associated with certain deadly diseases such as lung cancer and cirrhosis of the liver), law-enforcement applications (detecting airborne traces of explosives and drugs), environmental monitoring (detecting airborne pollutants and toxins), and military applications (detecting chemical warfare agents).



HOLLOW-CATHODE IONIZER

ION-MOBILITY SPECTROMETER AND ASSOCIATED COMPONENTS

The **Hollow-Cathode Ionizer** generates reactant ions which then ionize target organic species. The target ions are then analyzed in the ion-mobility spectrometer.

Portable gas-chromatography/mass-spectrometry (GC-MS) instruments that have commonly been used heretofore for detecting airborne organic compounds are characterized by three major shortcomings: (1) insufficient sensitivity for detecting sub-parts-per-billion concentrations, (2) susceptibility to undesired fragmentation of large organic molecules, and (3) the need for high vacuum and thus for high-vacuum equipment, which contributes greatly to size, weight, and mechanical complexity. In contrast, the PTR-IMS offers sensitivity adequate for detecting concentrations at the parts-per-billion level; operates in such a manner as not to fragment large organic molecules; and requires only a partial vacuum that can be generated by equipment smaller, lighter, and less complex than that needed for GC/MS.

The PTR-IMS includes a hollow-cathode ionizer, HCI (see figure), that

is designed to generate reactant ions (RH^+, where R is a reactant molecule) and to exploit a proton-transfer reaction. The HCI operates at a pressure in the approximate range of 1 to 5 torr ($\approx$ 0.1 to 0.7 kPa). H_2O is introduced into the discharge region inside the HCI, giving rise to the proton-transfer reaction

$RH^+ + M \rightarrow MH^+ + R$,

where M is the target molecule and MH^+ is the desired product ion. R is chosen to be a molecule that has a proton affinity slightly less than that of M, in which case the probability for fragmentation channels of the proton-transfer reaction is low and the process of "soft" ionization is dominant. Moreover, the reaction is highly selective: Molecules that have proton affinities lower than that of R do not enter the reaction. H_3O^+ is the most suitable proton-donor reactant ion for investigating trace chemical species in either Martian or Earth air because H_3O^+ does not react with CO_2, CO, H_2O, O_2, N_2, He, Ne, Ar, or Xe.

The ions produced by the HCI are introduced along with a sample of air into a reaction chamber. Product ions generated in the reaction chamber are detected and analyzed in the IMS, which was chosen over conventional mass spectrometers and other instruments because it offers the sensitivity needed for detection in the sub-part-per-billion range, can handle a wider range of molecules, and does not require a high vacuum (it can even operate at normal terrestrial atmospheric pressure). In the IMS, a bias voltage produces an electric field that causes the reactant and product ions to drift in a desired direction. At the downstream end of the drift region, ions are detected by use of a high-gain electrometer; typically, the detected ion current can be on the order of a picoampere. A microprocessor controls the operation of the instrument and the acquisition, processing, and display of data.

In order to enable the determination of drift velocities, the ions are introduced into the drift region in pulses at time intervals typically between 20 and 40 ms. Within the drift region, the ions undergo spatial separation based on both mass and shape. For a given electric-field strength, the drift velocity of a given ion species is directly proportional to its specific mobility. Smaller ions tend to travel faster. By measuring the ion-drift times under a particular set of conditions, one can construct ion-mobility tables that can be used for identification of unidentified target ion species.

This work was done by Isik Kanik and Luther Beegle of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-21187, volume and number of this NASA Tech Briefs *issue, and the page number.*

Books & Reports

Quantum Mechanics of Harmonic Oscillator in External Fields

A report presents a theoretical study of a harmonic oscillator in homogeneous or nonhomogeneous externally applied electric and/or gravitational fields. The standard quantum-mechanical formalism for a simple harmonic oscillator, starting with the Hamiltonian and the associated creation and annihilation operators, is modified to incorporate the additional terms representing the external fields. The correspondingly modified solutions of the Schroedinger equation are derived.

This work was done by Igor Kulikov of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Harmonic Oscillator in External Fields: Theory and Applications," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

NPO-30262

Algorithms for Collision-Avoidant Formation Flying

A report discusses algorithms for real-time planning of translation paths of multiple spacecraft flying in formation. The algorithm takes account of requirements to avoid collisions while operating within resource constraints (e.g., not calling for an acceleration greater than maximum possible) and striving for optimality (e.g., completing a change of formation in minimum time or at minimum energy cost). The optimality/collision-avoidance problem is formulated as a parameter-optimization problem, in which the translation path of each spacecraft is parameterized by polynomial functions of time. It is shown that this parameterization is the key to the solution of the parameter-optimization problem in that it enables decoupling of the collision-avoidance and acceleration-limit constraints, thereby making it possible to solve the problem in two stages. In the first stage, one constructs feasible paths that satisfy only the collision-avoidance constraints subject to certain optimality criteria. It is shown that the acceleration-limit constraints can be imposed *a posteriori* to compute the required maneuver duration such that at least one acceleration component is saturated. This also enables construction of paths that require minimum time in the class of solutions being considered.

This work was done by Gurkirpal Singh and Fred Hadaegh of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Collision Avoidance Guidance for Formation-Flying Applications," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-30332.

Integrated Colloid Thrusters for Microspacecraft

A report proposes the development of a microfabricated, integrated colloid thruster as a prototype of devices for propulsion and control of the attitudes of microspacecraft. (In a colloid thruster, a beam of positively charged, microscopic droplets is extracted electrohydrodynamically from a column of liquid and accelerated electrostatically to produce thrust.) Unlike other electrical thrusters, colloid thrusters are amenable to extreme miniaturization. The direction of thrust would be controlled electronically through selective activation of accelerator electrodes, eliminating the need for mechanical gimbals.

This work was done by Mohammed Mojarradi, Juergen Mueller, Jay Polk, and Colleen Marrese-Reading of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "A Fully Integrated Micro-Colloid Thruster System for Microspacecraft Applications," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Machinery/Automation category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-20945, volume and number of this NASA Tech Briefs *issue, and the page number.*

PCI Bridge to Instruments and Telecommunication Systems

A report describes a prototype system interface assembly (SIA) that performs the functions of a compact, radiation-hard application-specific integrated circuit (ASIC) to be built subsequently. The SIA ASIC would be installed in a spacecraft, where it would function as a peripheral-component interface (PCI) with (a) four scientific instruments that generate high-speed serial data streams and (b) either of two spacecraft telecommunication systems — the Small Deep Space Transponder (SDST) or the Space Transponding Modem (STM). Once configured, the serial uplink and downlink channels would conform to the SDST serial interface protocol or the STM modified serial peripheral interface protocol. In the SDST configuration, the downlink could be further configured for Reed-Solomon coding, for turbo coding, for bypass mode, and/or to enable a pseudo-randomizer. The SIA ASIC would operate in conjunction with a bus controller/remote terminal/monitor ASIC (United Technologies BCRTM or equivalent) to provide the control and status interfaces to the telecommunication systems and/or other systems that conform to MIL-STD-1553 devices. The ASIC would control, and would serve as an interface to, memory circuitry configurable by the user as external first-in/first-out buffers for each of the telecommunication and instrument interfaces.

This work was done by Anwar Akhtar, Martin Le, John Gilbert, Alfred Khashaki, Carl Steiner, Donald Johnson, Dwight Geer, Julianne Romero, Keizo Ishikawa, Kenneth Crabtree, and Leonard Day of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "PCI Bridge to Telecom and Four Instrument Interfaces," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*
NPO-30278

Effect of Gravitation on Noninteracting Trapped Fermions

A report presents a theoretical study of the thermodynamics of an ultralow-temperature gas of fermions that interact with a gravitational field and with an externally imposed trapping potential but not with each other. The gravitational field is taken to define the z axis and the trapping potential to be of the form $(m/2)(\omega_x x^2+\omega_y y^2+\omega_z z^2)$, where m is the mass of a fermion; x, y, and z are Cartesian coordinates originating at the center of the trap; and the ω values denote effective harmonic-oscillator angular frequencies with respect to motion along the respective coordinate axes. The single-particle energy is found from the solution of the time-dependent Schroedinger equation for a Hamiltonian that includes kinetic energy plus the gravitational and trapping potentials. The equation for the single-particle energy is combined with Fermi statistics to obtain equations for the chemical potential, internal energy, and specific heat of the gas; the number of trapped fermions; and the spatial distribution of fermions at zero temperature. The equations reveal the ways in which the Fermi energy, the specific heat, and the shape of the Fermion cloud are affected by the gravitational field and the anisotropy of the trapping field.

This work was done by Igor Kulikov of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "An Influence of Gravitational Field on Properties of Trapped Fermions," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*
NPO-30248

Improvements in a Piezoelectrically Actuated Microvalve

A report discusses the continuing development of a normally closed, piezoelectrically actuated valve fabricated mostly by micromachining of silicon. The design and operation of the microvalve as described in the instant report are basically the same as those of the version described in "Improved Piezoelectrically Actuated Microvalve" (NPO-30158), *NASA Tech Briefs*, Vol. 26, No. 1 (January 2002), page 29. Major elements of design described in both the instant report and the cited prior article include (1) a pressure-aided sealing configuration that contributes to the desired normally-closed mode of operation and (2) knife-edge sealing rings that reduce susceptibility to trapping of particles and the consequent leakage. The report also presents additional information concerning details of design and fabrication, including, notably, additional justification for knife-edge (in contradistinction to blunt-cross-section) sealing rings: The knife-edge sealing rings provide greater sealing pressure at a given sealing force, thereby reducing the leak rate and even making it possible to achieve an adequate seal with a hard seat. A potential additional advantage of the knife-edge/hard-seat design is that contact pressures may be high enough to crush contaminant particles, thereby reducing the leakage attributable to contaminants.

This work was done by Eui-Hyeok Yang, Larry Wild, and Nishant Rohatgi of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "A Micro Valve for High Pressure Applications," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-30338, volume and number of this NASA Tech Briefs *issue, and the page number.*

Low-Energy Transfer From Near-Earth to Near-Moon Orbit

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This work was done by Martin Lo, Jerrold Marsden, Wang S. Koon, and Shane Ross of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Low Energy Lunar Transfer and Capture," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category. NPO-20936*

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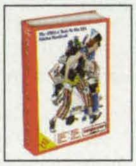

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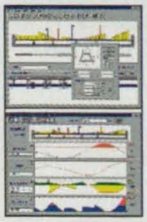

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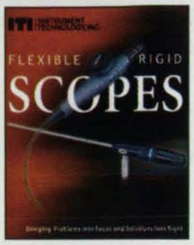

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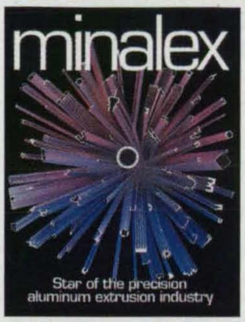

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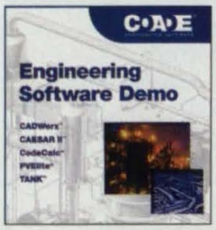

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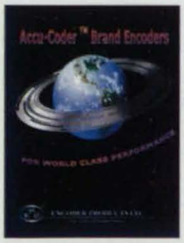

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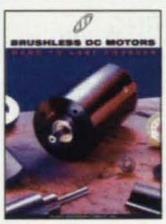

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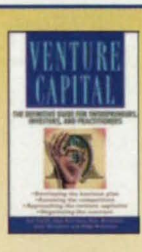

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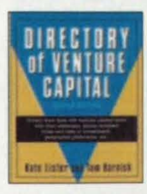

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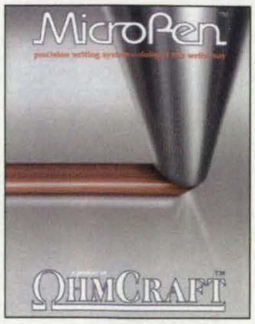

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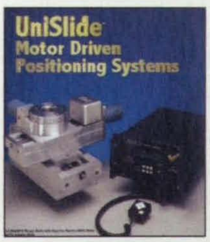

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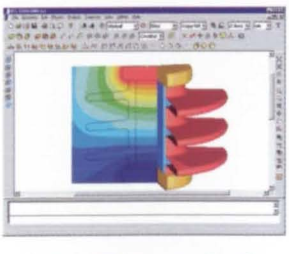

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